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HISTORY OF THE MINISTRY OF MUNITIONS

Vol. 7-8
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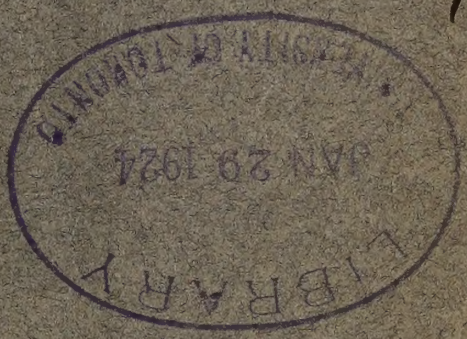
VOLUME VII

THE CONTROL OF MATERIALS

PART I

REVIEW OF COMMERCIAL CONTROL

101



1922

I



VOLUME VII

THE CONTROL OF MATERIALS

PART I

REVIEW OF COMMERCIAL CONTROL

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CHAPTER I.

THE BEGINNINGS OF CONTROL.

I. Introduction.

A review of the control of British trade and industry by Government Departments during the war would certainly emphasise the fact that control, though inevitable, was tardily and unwillingly undertaken, and this general statement is strongly supported by an examination of the controls exercised by the Ministry of Munitions. For nearly a century the country had prospered under the individualistic doctrines of the *Laisser Faire* school; Free Trade had flourished for more than seventy years, and though the first years of the twentieth century saw the beginning of a reaction and a large extension of the State's activities with regard to labour and industry, Government control was still much less familiar and less easily developed than abroad. Thus, during the war, France with her doctrines of liberty, equality and fraternity accepted a State control of labour of a character far more stringent than that admitted in England, while in Germany, as soon as war broke out, the State created machinery for controlling raw materials, rationing their distribution and fixing their price.[1] Similar machinery was finally evolved in Great Britain by a lengthy, painful, and often illogical process, Government control being extended to meet emergencies as and when they arose. State control was therefore slow in its development and unscientific in its application. It was never extended until the necessity for it became clamant, but this halting process was in harmony with the spirit of a nation which has always preferred individual liberty to order, freedom to logic, opportunism to principle.

Since State control followed rather than forestalled necessity, it was usually accepted with comparative willingness. In some few instances State control actually lagged behind public opinion, and was imposed as a result of popular pressure. But, as a rule, jealousy of Government control only yielded to a complete conviction of its necessity, and the danger of too rapid an extension of it was revealed by the outcry which followed any measure which could be construed as a threat of industrial conscription, by the unpopularity which State control of trade had attracted by the end of the war, and by the increased dislike of bureaucracy and bureaucratic methods.[2] In fact, it appears probable that experience of State control during the war has retarded rather than hastened the spread of State socialism.

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[1] In Germany a Raw Materials Department was established under the Ministry of War to organise the distribution of the raw materials on which an embargo had been placed. Trading companies were established to purchase and distribute supplies of raw materials to the best national advantage. (Hist. Rec./R./600/20, p. 4.)

[2] See below, pp. 98–103.

Another factor which tended to limit and retard the growth of State control during the war was the small size of the Civil Service in Great Britain as compared with bureaucracies abroad. Each development of the State's activity meant a corresponding increase in the administrative services, and raised a considerable staffing problem. When the Ministry of Munitions was formed, Mr. Lloyd George met this difficulty by the expedient of employing successful business men in many of the chief posts, and this example was followed when other new Ministries were formed. But there still remained the difficulty of finding really competent temporary staff in the lower grades and in spreading the traditions of the Civil Service among the immense staffs of the new Ministries—the headquarters staff of the Ministry of Munitions alone numbering 25,000 at the date of the Armistice.

All these factors together explain the reluctance of the Government to assume control, and the postponement of control to the last possible moment in nearly every case, with the result that, when the Armistice was signed, control of material and industry was only just getting to the stage reached in Germany when the war began, and control of labour, which had actually been relaxed to some extent in 1917, fell far short of the control exercised in France from the beginning.[1]

The movement towards increased control of labour and industry proceeded on parallel lines. The change from voluntary enlistment to conscription and the evolution of a scheme of National Service, foreshadowed but not realised during the war, had its counterpart in the process by which materials and machining capacity were controlled. But in these latter cases control was less halting and incomplete. The work of controlling machining capacity, which began with Regulation 8 under the Defence of the Realm Act and had been experimented with on a small scale in the early months of 1915, received a great impetus when the Ministry was formed. Under the Munitions of War Act hundreds of establishments were declared to be "controlled," manufacturing methods, as well as wages and profits, coming thereby under State regulation, while the evolution of the Priority Department provided machinery for distributing claims on manufacturing capacity in the order of their urgency. This form of control became increasingly stringent with the progressive shortage of materials and culminated in the establishment of the Priority Committee of the War Cabinet which made control complete and effective. By the end of the war, no one could start a new business or enlarge an old one except for war purposes; everyone was liable to have buildings, plant or machinery requisitioned for more urgent work; while none of the industrial metals and few raw materials upon which the country's industries were based could be used without a license from one Government Department or another. The materials controlled by the Ministry of Munitions alone, which are exhibited in an Appendix[2], ranged from acetone to zinc, and included all forms of steel and iron, the chief non-ferrous metals, the chief coal tar products, industrial acids and fertilisers. The control

[1] For a full account of Labour Administration, see Vols. IV, V, and VI.

[2] Appendix I. For an account of the controls exercised by the Department of the Surveyor-General of Supply at the War Office, see below pp. 125–50.

of raw materials was indeed stricter than in any of the Allied countries, and British merchants and manufacturers had some ground for complaining that economies forced upon them were not adopted abroad, and that some of the materials saved by sacrificing British export markets were dissipated by the extravagance of Allied manufacturers who were less rigidly controlled.[1]

In the competition for munitions materials Great Britain could draw on the resources of a world wide Empire, but these resources, though of enormous potential value, were imperfectly developed. Of some vital munitions materials, like tin and mica, the British Empire produced by far the largest amount, and its strong position with regard to the supply of these became a valuable counter for diplomatic bargaining and exchange with the United States and with neutrals. Of other vital commodities like coal and steel she had a supply which, while abundant in normal times, was barely sufficient for the exigencies of war, and had to be husbanded and distributed with the most careful exactness. A third class of war materials like iron ores, nitrates, copper, and aluminium came from friendly neutrals and the United States of America. Great Britain's power of acquiring these materials was only limited by the amount of the surplus available, by her command of foreign currencies and credit, and in the later stages of the war by the amount of shipping available. Both the last limitations became increasingly serious, while the first became less powerful, with the stimulus to production given by war demands, and with the increasing strictness of the blockade which virtually shut Central Europe out of the market altogether, her supplies through Border neutrals being cut off by naval and diplomatic pressure.

As will be seen below, Great Britain depended for certain essential materials[2] upon certain of the Border neutrals who might conceivably become enemies, and when this dependence was so pronounced as to become dangerous the Ministry had to foster attempts to produce such materials or substitutes for them in Great Britain.

But there remained a fourth class of materials or manufactures essential for munitions production the supply of which, or some necessary process in the production of which, was almost monopolised, when the war broke out, by Germany and her Allies. Of these the most important were optical and chemical glass, potash, spelter and tungsten, and a large number of miscellaneous articles ranging from magnetos to hosiery needles and lamp glasses. In some of these cases, though the source of the material lay within the British Empire, some of the processes essential for their utilisation had before the war been carried out wholly or mainly in Germany. Zinc concentrates and wolfram ores, for instance, produced in Australia had been smelted and refined in Germany, and in order to obtain supplies the Ministry had to set up new industries in the United Kingdom or expand small scale industries. In the same way, Australian lead was controlled by German financial interests. Germany again, had acquired control of the bulk of the Indian mica mines; and the chief market for mica was at the

[1] *e.g.* Report of conference on 2 February, 1917. (HIST. REC./R/1810/71).

[2] *e.g.* ferro-chrome from Norway and special steels and irons from Sweden.

outbreak of the war, on the point of being transferred to Hamburg. The extent of the influence exercised by the *Metallgesellschaft* at Hamburg over the other metals in the non-ferrous metal group was debateable, but such controls as existed had to be broken down and the trade organised in new channels by the Ministry.

The development of these new industries ancillary to munitions production, and of the munitions industries themselves involved financial help from the Government on a very large scale. The principles governing the varied methods of giving financial help, whether by loans bearing interest or interest free, by advances repayable from the price of the store or irrecoverable, by direct contributions to the cost of new buildings, by contribution by way of an allowance or writing-off from excess profits, by supplying raw material below cost or subsidising production in some other form, are considered in detail elsewhere,[1] but it is important to notice here not only that the State became financially interested in industry to an extraordinary and unprecedented extent, owning in some cases a considerable portion of the ordinary shares of commercial undertakings, and nominating directors to sit on the boards of companies,[2] but that industry was placed upon an artificial basis to the extent of the State's contribution. In some trades, like the subsidised iron and steel industries, the artificial character of prices and production costs was frankly recognised, but many of the other industries financed by the State depended upon Government help, and could only be profitably operated if war time demand continued. Some of them, like the glass and chemical dye industries, could flourish only in the absence of competition from Central Europe, others, like aluminium refining, would be threatened by the improvement of transport conditions restoring competition from countries possessing abundant water power, others like non-ferrous mining depended on high prices and absence of competition from larger mines abroad. Some of the capital invested in these industries represented a permanent addition to the nation's industrial wealth, many of the steel and blast furnace extensions, which replaced antiquated by modern plant, falling into this category; in other industries part of the value of the plant could be utilised by a change in the form of the product, as by the conversion of cellulose works to the manufacture of artificial silk, of explosives factories to ordinary chemical work, or of shell or aero-engine shops to the production of locomotives, motor cars or sewing machines. But in many cases the value of the capital invested could not be realised after the war was over, owing to the smallness of the normal peace demand and the specialised character of the product, ammunition filling factories and aeroplane works being the most conspicuous examples of this compulsory waste of wealth.

In reviewing, therefore, the control exercised by the Ministry of Munitions, it must be remembered that the diversion from peace to war activities was made on a scale that could not have been possible without State help, owing to the reluctance of private capitalists to

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[1] See Vol. III, Part III.; Vol. X, Part III, Chap. VI.

[2] In a few cases the Ministry owned all the shares and nominated all the directors. (HIST. REC./R/400/43).

finance developments that had a comparatively small post-war utility. Moreover, the measure of the State's success in diverting industry into new channels was the measure of the problem that had to be faced when peace conditions returned, a problem complicated by the effects of State control of labour during the war period.

II. The First Steps towards Control.

The necessity for Government control, of course, originated in the shortage of essential war materials, due to a variety of causes of which the chief were the increased demand, the loss of supplies from enemy countries, and a temporary decline in production due to the dislocation caused by the war. The shortage of certain materials for the manufacture of high and propulsive explosives was felt almost at once, and it is in connection with them that some of the methods of control destined later to have such great developments—prohibition of export, requisitioning of stocks, compulsory changes in processes of manufacture—were first adopted. A brief review of these first tentative steps may be useful. Naval stocks of explosives materials were small, army stocks were negligible.[1] Curiously enough the first material of which a shortage was felt was toluol, a bye-product of the gas and coal-tar industry carried on in Great Britain on an enormous scale, and indeed, first developed there. But the processes of toluol and benzol recovery discovered in Great Britain had not been carried on there on a commercial scale, and the industry had been developed in Germany where it flourished in connection with the dye industry. The shortage of toluol was emphasised by the increased demand for the new explosive. T.N.T. (tri-nitrotoluol) had been adopted by the British Army just before the outbreak of the war, and the War Office took steps (3–5 August) to conserve the materials for its manufacture and that of the other standard explosive, picric acid, by prohibiting the export of benzol, coal-tar toluol, phenol, nitro-toluene, etc.[2]

This was one of the earliest examples of the policy of restricting exports of war materials, which formed an important part of the machinery of control, and which will be considered below.[3] As the use of high explosives, especially of T.N.T., developed it became apparent that the resources of the whole country would be required to meet military demands, and in November 1914 power was taken to requisition all the supplies of toluol available in the United Kingdom. A generous price was paid for the toluol requisitioned under this Order, so as to stimulate production, a small quantity, about 400 tons per annum, being diverted to the manufacture of dye stuffs.[4] Thus the powers already exercised by the military authorities with regard to buildings,

[1] A small reserve of acetone and oleum had been accumulated before the war to meet the needs of the Royal Gunpowder Factory, as the country depended almost entirely upon overseas supplies, but of other materials there was no reserve. See Vol. VII, Part IV, p. 1.

[2] Vol. VII, Part IV, p.11.

[3] See below, pp. 22–26.

[4] In April, 1915, the entire output of the makers of phenol was taken over for the period of the war, a high price being paid in order to stimulate production.

animals and warlike stores were applied to another form of war material, and the precedent thus set was widely followed by the Ministry of Munitions later on.

A third landmark in the history of war control of materials—the regulation of manufacturing processes—was also reached in connection with toluol, the distillers being compelled to recover from the benzol or naphtha sold by them all toluene in excess of three per cent. (December 1914).[1]

Meanwhile, the War Office was trying to supply itself with these and other necessary materials in the United States, and here another factor which hastened the development of control in the form of centralised buying appeared—the great rise in prices due to the increased demand, and accentuated by trade competition, by the competition of other Government Departments and of Allied Governments, and by speculation. The appointment of an American banking firm to act as purchasing agents for munitions and munitions materials required by the War Office in America, which is considered in detail elsewhere,[2] was an attempt to counteract the effect of competition between Government Departments for American supplies, and eliminate brokers and middlemen. But this step, successful as it was in diminishing competition for finished munitions, did not remove the competition between manufacturers of munitions for munitions materials. The only way of checking this competition was for the Government to become responsible for supply, undertaking purchases and controlling distribution. The War Office was not inclined to shoulder this unprecedented responsibility, and though repeatedly pressed by its purchasing agents to make large forward purchases of material was reluctant to do so. Moreover, the large and experienced firms to whom the War Office at first confined its munitions contracts had their own highly efficient organisations for buying material, and there appeared to be little necessity for the intervention of the Department.

At the beginning of 1915, however, an increased stringency was discernible, which revealed itself at first in the American market, where the buying agents of British munition makers were competing with each other and forcing up the prices of materials. This reacted at once on munitions contracts in England, and resulted in demands for higher prices on new munition contracts and even on running contracts. The danger of allowing this process to continue was apparent, and the War Office began to make purchases of explosives materials, of which the shortage was most obvious. This policy was rapidly developed as soon as the decision to spread munition contracts brought in comparatively inexperienced firms, who were more dependent on the Department for assistance in getting materials. Almost simultaneously the Armaments Output Committee undertook to supply the National Shell Factories, which were then being planned, with material.

During the three months that immediately preceded the formation of the Ministry of Munitions, therefore, the War Office was beginning to make purchases of material, at first as a reserve, and then with

[1] Vol. VII, Part IV, p. 15. [2] See Vol. II, Part III.

a view to meeting the responsibility for distribution to new and inexperienced contractors and to the new shell factories. In this development of Government buying, materials for explosives came into prominence first, and the first adventures of the War Office in the American market for materials were in connexion with toluol, picric acid and oleum, which it was buying from September, 1914, onwards. In February, 1915, the shortage of toluol was so serious that the War Office was forced to buy at high prices up to $2 per gallon all the toluol offered for delivery in America by the end of the year.[1] It was hoped that by that time sufficient supplies would be obtained from home sources, and the War Office wished to reduce its purchases of toluol at the " ridiculous price " then ruling, to the minimum.[2] The Ministry inherited the reserve thus formed, and having ascertained by enquiry that its American contractors had secured ahead the supplies they required, was able to leave the American market alone while British sources of supply from coke ovens and gas works were being opened up.[3]

In the same way the War Office had to buy picric acid, T.N.T., cordite and nitrocellulose powder, at high prices, which had been enhanced by the activities of brokers, by speculation and by the competition of France and Russia.[4] The War Office wished to confine its activities to immediate needs, and was unwilling to buy materials for delivery after July, 1915, and it was not until after the formation of the Ministry and the complete acceptance of responsibility for supply, that purchases were made for delivery throughout the following year.

The position with regard to one of the necessary solvents—acetone—was specially difficult. With the exception of the reserve stock held at the outbreak of war at the Royal Gunpowder Factory and the output of the Forest of Dean Factory set up in 1913, both Waltham Abbey and the trade were entirely dependent upon American supplies, most of which were controlled by a single group, the price rising to double the pre-war price. After a period during which Messrs. Nobel's bought for the trade and the War Office, through Messrs. Nobel's agents, for Waltham Abbey, the War Office decided (April 1915) to undertake the responsibility for buying all the acetone required by trade makers of explosives for use in 1916, on condition that they refrained from entering the market on their own account.[5] This is one of the first examples of Government buying for the trade which was destined to great development later by the Ministry of Munitions. From the Government reserve thus created loans were later made to tide cordite makers over a difficult period.[6]

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[1] L. 2108, 2114, 2120, 2189, 2206, 2644 ; N.Y. 1094, 1111, 1144, 1149, 1162, 1174. (A complete set of the cables is filed in the Archives Registry.)

[2] L. 2454.

[3] L. 6206 ; N.Y. 5279.

[4] L. 2573, 1001, 1008, 1089 *Seq* ; N.Y. 1003, 1006, 1075 *Seq* ; N.Y. 1223, L. 2122, N.Y. 5134, 5715, 7500 ; L. 5094, 8281.

[5] N.Y. 1135, 1586, 1819, 1920, 3261, etc. ; L. 2158 2489, 2587, 2693, 2717, 2829, 2905, 2947, 4275, etc.

[6] N.Y. 7227 ; L. 8094, 8467.

The rising price of acetone in spite of the arrangements for reducing competition by centralising purchase led the War Office to try and find other sources of supply, and in April, 1915, financial help was given to a firm undertaking the production of acetone from potatoes, this being one of the first examples of the development of new or alternative processes being financed by the Government.

The next group of munitions materials in which purchases by the Department were undertaken consisted of certain non-ferrous metals—brass, copper, aluminium, etc. The Board of Trade had made certain purchases of copper in America for distribution to the trade, but the War Office refused at first to extend to metals the responsibility which had been forced upon it with regard to explosives materials, and confined its purchases of metals to the demands of the Ordnance Factories which could be covered without difficulty, though on a constantly rising market. In the spring of 1915, however, the effect of the eager demand of munition makers for these materials, coupled with the operations of speculators, had forced the market up to unheard of prices, and the War Office had to reconsider its attitude. The gradual process of conversion may be illustrated by the case of spelter. On 14 January, 1915, the American agents were informing the War Office that the market was practically bare of the high grade zinc and spelter essential for the production of cartridges, and that production for the next four months had been bought up, and urging them to secure essential supplies.[1] The War Office refused to consider this suggestion, but the market advanced rapidly, and in May the Department decided to buy 1,000 tons at a greatly enhanced price, and suspecting "a gigantic manipulation of the spelter market by German interests with a view to depriving the Allies of munitions of War" urged its agents to suggest any means of counteracting or fighting the ring.[2] The suggestion of an enemy ring proved groundless, and the extraordinary rise in the metal market was attributed by the agents to Russian orders and to private buying by British munition makers. The only way of counteracting this was by departmental purchase of the supplies required by munitions makers, and the War Office was beginning to take steps in this direction when its duties were transferred to the Ministry of Munitions, which, as will be seen below, soon accepted and developed the responsibility for supplying material to its contractors. Large purchases of brass rod were made in the United States during July, August and September, 1915, for distribution to Swiss and French makers of fuses, twelve months' contracts being placed in order to secure continuity of supply. A few British fuse makers were already depending upon the Ministry for the supply of material, but the bulk of them were still placing their orders independently.

The responsibility of the Ministry with regard to the supply and distribution of steel arose comparatively late owing to the fact that, as Great Britain was one of the three great steel producing countries of the world, there was no shortage until the middle of 1916. The rise in

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[1] N.Y. 1010.

[2] N.Y. 3236, 3509, 3511, 3660, 3696, 5095, *Seq*, L. 4512, 4534, 4663, 4659; L. 6009.

prices, however, had already caused anxiety, and one of the first acts of the new Ministry was to fix, by agreement with the trade, maximum prices for shell steel, prices for commercial steel being settled soon afterwards.[1] Early in 1916, however, it was clear that the existing rate of output would be insufficient to feed the National Projectile Factories which were then being rapidly erected, and by the direction of the Ministry, and with liberal financial help from the Government, extensions to steel works were planned on a large scale.

As in the case of non-ferrous metals, the armament firms at first supplied themselves independently of the Ministry, many of them being also steel makers, but the increasing shortage, which from the autumn of 1916 affected all classes of steel, made more rigid control necessary. For various reasons, though steel works and blast furnace extensions were begun on an enormous scale, supply never kept pace with demand, and the steel problem was the governing factor of all munitions programmes during the later years of the war, while, as will be seen below, the chief preoccupation of the Ministry Priority Department, and later of the Cabinet priority organisation was the problem of the best distribution of the inadequate supplies of steel. One of the chief features of the control of steel by the Ministry was the elaborate system of keeping prices fixed by subsidy, which is considered in detail elsewhere.[2]

III. The Growth of Control.

Thus by the time the Ministry was founded the principle of Government control of munitions materials was admitted, and the War Office had already introduced many of the methods which were later established as part of the ordinary machinery—control of exports, commandeering stocks and output, and centralised purchasing—while it had made certain experiments in controlling methods of manufacture, and had accepted a limited responsibility for distributing supplies to contractors. But the remaining three years of the war saw great developments.[3]

Once any measure of control had been undertaken the forces pressing for complete control became stronger and were ultimately irresistible. Partial control was unjust as well as unsuccessful, and control of supply created monopolies which had to be met by controlling prices.[4] Thus if imports were restricted without prices being controlled, Government Departments and the consuming public had to pay higher prices, and the rise continued until legal control was imposed. Again, when piecemeal Control Orders were issued, when the War Office, for instance, commandeered the output of particular firms or districts, it had the immediate effect of raising the price of uncontrolled supplies for other Departments. Again, control of completed stores and munitions made it necessary to control the raw materials or components

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[1] See Vol. VII, Part II, Chap. VI.

[2] *Ibid.*

[3] For an account of a similar development of State control in the Department of the Surveyor-General of Supply, see below, pp. 125–50.

[4] Munitions Contracts Board Minutes 495(2/8/18, 14/8/18).

of which they were made. Further, control of a material or store usually involved sooner or later the control of substitutes for it, in order to prevent the price of such substitutes being inflated. Efforts to escape fixing prices by Order, by means of voluntary agreements with the trade were not always very successful and nearly always led to control by Order. Thus, the steel and iron prices fixed by voluntary agreement were soon exceeded and had to be legalised in order to avoid penalising the more patriotic firms, and control of non-ferrous metal prices through the London Metal Exchange was followed by control by Orders under the Defence of the Realm Act.

Another of the factors driving the Ministry to assume control of any material was the difficulty of securing that all requirements for munitions purposes were covered without such control. The following report clearly summarises the position at the end of 1916 :—[1]

> " One of the great difficulties experienced in making arrangements for supply is the fact that in certain cases contractors can please themselves as to whether they purchase their material in the open market or come to the Ministry for it. The Ministry thus more or less undertakes to supply any contractor who may come to them for metal, and consequently the commitments of the Ministry at any particular moment can never be clearly forecasted. In view of the present scarcity of raw material, firms who may not in the past have experienced any difficulty in obtaining supplies may very well be caught short unexpectedly."

The efforts to postpone or escape the necessity of control may be illustrated by the case of brass and spelter. The Raw Materials Department was reluctant to take over control because it would involve much administrative work and much larger staffs, but the Minister emphasised the danger of a situation in which the supply of brass for munition purposes depended on contractors importing on their own account sufficient material to cover their munitions contracts. They were likely to postpone coming to the Ministry for help until they had exhausted the usual trade channels; there were no accurate statistics of the stocks they kept, or of the amount they imported, but in the last resort the Ministry had to see that they had enough metal to keep them going. The Ministry therefore had the responsibility for averting a shortage without the power of preventing it.[2] Though control meant more work it meant safety. The Ministry would be in possession of accurate information as to the actual and potential output of the country, and the importation from abroad, and would be able to balance total demands against the whole of the supply available—figures hitherto given being vitiated by the non-appearance of the stocks which makers were acquiring independently of the Department.[3]

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[1] Report on Metal Requirements, by Mr. Ronald Williams, 25 November, 1916. (CR. 4418.)

[2] Most of the arguments for and against control in the case of brass applied to the general question of controlling material (Minutes of Fortnightly Meetings with Heads of Departments, 15/1/17).

[3] C.R. 4418.

The stages by which the Ministry assumed control of any material not hitherto controlled are an indication of the way in which the unwillingness to extend the Department's responsibilities was overcome by the pressure of necessity. At first the Department simply bought supplies for the manufacturing demands of its own factories. The next step was to buy considerable supplies of those materials of which an increased shortage was anticipated, to be held as a reserve to help manufacturers who found themselves short of material. Next the Department took over the whole responsibility for supplying all Government factories and organised a system of distribution. By this time, all the smaller contractors were looking to the Department for supplies of material, which were being issued to them at a fixed price, and soon the larger contractors also abandoned their system of private purchase and were supplied from the Department. The final step was to assume responsibility for all visible supplies, to control all private importation and distribute material to non-munitions as well as munitions trades, thereby virtually bringing all the industries connected with munitions supply, and all the industries using munition materials, including private as well as munitions trading, under the control of the Department. The control of most munitions materials went through these stages, though the various stages were reached at different dates. The only rough generalisation possible is that control came first in connection with materials for high and propulsive explosives, being followed in succession by the control of most of the non-ferrous metals, optical and glassware materials, iron and steel and aircraft materials.

Throughout, the Ministry acted in very close co-operation with the trade or industry controlled. Frequently, important members of the trade had official posts and executive authority in the Ministry ; while in these and in other cases an Advisory Committee representing the trade was appointed by the Minister to advise the department or section of the Ministry concerned. Frequently the Ministry consulted and negotiated with an association or society representing the trade and discussed the necessity for, the scope, and probable effect of its Control Orders with that body. Where such a body did not previously exist the Ministry stimulated the formation of such representative organisations in order to simplify its negotiations. Important firms were also entrusted with the purchase on commission of certain metals and materials required by the Government in foreign markets, and it was claimed that their expert knowledge effected savings out of all proportion to the cost of their work, while their personal acquaintance with the sellers faciliated delicate negotiations. The contact with the trade was perhaps closest in connection with non-ferrous metals, and the London Metal Exchange was so completely in harmony with the views of the Department, that regulation by it was for a time an efficient substitute for direct Ministry control.

This close contact with the trade was not without its disadvantages. It made the Ministry control more efficient, but firms who were not represented on the Advisory Committees, or who had been trade rivals of Ministry officials, naturally viewed with suspicion activities which conflicted with their private interests, and in particular were hostile

to examination of books by trade competitors. Though in isolated cases such suspicions were perhaps well founded, these were insignificant when weighed against the reputation for disinterested conduct earned by the majority of these traders turned officials, and the great advantage of framing war rules for a trade in accordance with the advice of men who had spent their lives in it. In fact, it may be said that a large measure of the Ministry's success in controlling materials was due to its intimate knowledge of the trades affected, and that without this co-operation with the leaders of industry failure would have been almost inevitable.

In the meantime other Departments were extending their controls by the same opportunist methods. The result was a maze of Control Orders issued sometimes by this and sometimes by that Department, according to the historical accident which determined control in the first place. The Ministry controlled building bricks, but the War Office controlled cement for concrete and so on, and occasionally one Government Department issued Control Orders without consulting the other Departments interested, difficulty and confusion resulting. On the other hand, it was contended that elaborate inter-departmental discussion beforehand would lead to disastrous delay, and in some cases defeat the object of the proposed Order by allowing its contents to leak out beforehand. Mutual co-operation appeared to be more valuable in allocating materials than in the preparation and issue of Orders.[1]

The general principle that emerged, at first dimly, and then clearly, was that control of any war material should be assumed and administered by the Department most largely concerned in maintaining supply. Thus the War Office controlled textiles, the Admiralty controlled oxygen and the Ministry steel, as is seen in detail elsewhere. But though this principle was accepted with regard to supply, with little friction, its operation with regard to distribution was not admitted without conflict, especially in cases where two or more Government Departments were vitally concerned. Thus there were struggles between the Ministry of Munitions, the Board of Trade, the Controller of Food, the Ministry of Shipping and the Coal Controller over oils and fats, tonnage rates, fuel and power, which, as the competition for materials became more acute, had to be taken to the Cabinet for settlement, but the chief protagonists were the Ministry of Munitions and the Admiralty, and the chief cause of contention was steel. The only solution of these difficulties was the creation of an organisation deriving its authority from the Cabinet, which had power to bind the contending Departments, and the evolution of a Cabinet priority organisation is described in a later chapter.[2]

IV. Methods of Control.

Control of materials involved control of existing supplies, development of new sources of supply and control of distribution.[3] The control of supply could of course only be complete when the State had or could

[1] C.R.V/Gen/1404. [2] See below, Chap. IV.

[3] Compare the account of the Department of the Surveyor-General of Supply given below, pp. 125–50.

secure control of the materials at their source, and this occurred but seldom. On the other hand, judicious purchase in the chief markets or the arrangement of forward contracts with producers could give security of supply second only to control at the source. Within certain limitations of credit and shipping which have already been referred to, the Ministry could draw on the whole world with the exception of Central Europe. The United States of America was of course the chief source of all the munitions materials that could not be obtained within the British Empire, and fortunately for the Allies the American Government came into the war just when the difficulty of finding dollars to finance British and Allied purchases was becoming acute. Supplies from Canada are interesting owing to the great growth in their value, which is a measure of the industrialisation of the Dominion during the war ; supplies from Australia presented special tonnage difficulties, and opened up post-war problems of non-ferrous metal control ; while the supplies from India and South Africa are an interesting illustration of the development of Imperial resources. Spanish supplies of iron ore were also of special importance, both from their bulk, from the fact that they were vital for steel production, and from the fact that the voyage was especially hazardous. The chief feature of the Scandinavian supplies is their importance compared with their bulk and value, and the delicate diplomatic problems involved. The tonnage problem involved in transporting materials from these distant markets has been considered elsewhere;[1] the chief point in this connection is the complexity of the problem of securing supplies from so many different sources, and from States standing in different relationships to the Allied Governments.

It will be found that the method by which the Ministry secured the necessary supplies of materials from existing sources varied infinitely, but it is possible to group its activities roughly as follows :—

(1) commandeering existing stocks and purchasing future output;
(2) centralised purchases in foreign markets ;
(3) restriction of export and import.

These activities together with the cognate subject of the control of prices, will be considered in Chapter II. Chapter III will contain an outline of the development of new sources of supply, while a sketch of the control of distribution and of the priority system will be found in Chapter IV and Appendix IV.

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[1] See Vol. VII, Part V.

CHAPTER II.

SECURING AND CONTROLLING SUPPLIES OF MATERIAL.

I. Purchasing Stocks and Output.

Obviously, the quickest way of securing any scarce war material of which supplies were to be found within the United Kingdom, was to exercise the power of requisitioning it. The War Office exercised these powers under Section 115 of the Army Act, under the Army (Supply of Food, Forage and Stores) Act and by Regulation 7, issued under the Defence of the Realm Act, and when the Ministry was formed it was given concurrent powers with the War Office.[1]

As has been seen, the first munitions materials to be requisitioned under these powers were toluol, phenol and benzol.[2] The precedent set by the War Office was followed by the Ministry, and requisitioning stocks and output became the basis upon which home supplies of the chief munitions metals and materials were secured. The method of purchasing in advance the whole output of an industry, at first for a definite term and later for the duration of the war, was widely adopted by the Explosives Supply Department ; practically the whole output of certain materials obtained as by-products in important industries like the gas industry, the coke industry, the soap trade and the dye industry, were taken over by the Ministry for the duration of the war.[3] In the same way the Ministry secured the whole British output of non-ferrous metals,[4] of optical stores and glass, of linen and flax,[5] and a very large proportion of the output of the iron and steel trades.[6] Occasionally the contract extended, as in the purchase of Australian concentrates, for a term of years after the war.

Requisitioning in its narrower sense was much less important than taking over the entire output of the industry, but instances of the former are common. Sometimes the stocks of one firm only were requisitioned, usually for disciplinary purposes, as in the case of firms which refused to sell their stocks of platinum, aluminium and fine zinc at a reasonable price, and sometimes material was requisitioned to meet a temporary shortage, as when all the glycerine in the country, as well as the future output, was taken over in July, 1915,[7] or when dormant printers' metal was taken over to relieve the lead shortage.[8] The terms under which the output of an industry was taken over were negotiated by the Department with representative associations, or, if such did not exist, with leading members of the trades concerned, and

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[1] See Vol. II, Part I. An account of the purchasing methods of the Department of the Surveyor-General of Supply at the War Office is given below, pp. 125–50.

[2] See above p. 5 and Vol. VII, Part IV, Chap. II.

[3] See Vol. VII., Part IV.

[4] See Vol. VII, Parts II and III.

[5] See Vol. XII, Part I, Chap. V.

[6] See Vol. VII, Part II.

[7] Vol. VII, Part IV, p. 79.

[8] Vol. VII, Part III.

firms who did not agree with the terms thus negotiated had to submit to requisitioning.[1] When the Ministry took over output in this way, physical possession did not necessarily follow, but the output was checked by officers of the Department, and distributed to munitions firms in obedience to its directions.

II. Centralised Buying in Foreign Markets.

(*a*) Purchase by Government Departments.

As has been seen, the War Office had extended its sphere of action to the purchase of certain munitions materials which were in short supply, and the Ministry developed this purchasing activity to an enormous extent. After urgent needs had been met, and reserves formed, departmental buying was continued in order that supply might be steadily maintained.[2] The chief market throughout the war was the United States, and the effect of centralised buying in reducing competition and speculation and diminishing prices was already marked when the Ministry began its work. The appointment of the banking firm of Messrs. J. P. Morgan & Company as agents to effect War Office purchases had produced good results in eliminating brokers and middlemen, developing new sources of supply, and diminishing prices,[3] and the firm continued to act as agents for Ministry and War Office purchases until the middle of 1918, when their functions were taken over by the Ministry's purchasing department in America.

This was by far the most important agency, but other commercial firms were appointed as agents for the purchase of special materials. Thus cotton waste, whale oil and acetic acid were bought through trade associations, special irons and steels were bought in Sweden, ferro-silicon in Norway, magnesite in Greece, mica in India, bismuth and chrome ore in South Africa by agents appointed by the Ministry and remunerated on a commission basis. All Government purchases of petrol were made through a Pool Board, consisting of the chief importing and distributing companies.

The principle which ultimately governed centralised buying was that the Department chiefly concerned with supply should be responsible for purchase for its own needs, for the needs of other Departments, and finally, in the case of imported supplies, for the needs of the commercial community. It was long, indeed, before this principle, though its validity was early recognised, was generally adopted in practice. Departmental conservatism and the reluctance of traders to forsake their usual channels of supply delayed full centralisation. As late as June, 1918, for instance, the War Office, Admiralty and Ministry of Munitions were buying steel wire independently, and the disadvantageous competition which resulted was only remedied by the decision that the Admiralty, which bought 90 per cent. of the requirements,

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[1] *e.g.* Vol. VII, Part IV.

[2] The steadying of the markets achieved by judicious buying at favourable moments was considerable. See Vol. VII, Part III *passim*.

[3] See Vol. II, Part III for an account of the work of this agency.

should buy the whole ; [1] while the Contracts Department of the War Office was still buying steel work in the form of bridges, pontoons and Nissen huts independently of the Ministry.[2] Again, the War Office was by far the largest buyer of cotton fabrics, but the Admiralty was unable to agree that the War Office should buy the fabric required for airships, as they alone had the special knowledge required.[3] Many other exceptions to the operation of the general principle above referred to might be quoted, but broadly speaking, the responsibility of the Ministry of Munitions for the purchase and distribution of explosives materials, of the non-ferrous metals, of the materials for chemical warfare and for glass manufacture, and of iron and steel materials was fully recognised. Thus the Ministry became the largest buying and the largest selling concern in the world, with a turnover amounting to hundreds of millions yearly.

The operation of the same principle distributed responsibility for purchase and control among the various departments of the Ministry. Thus the Explosives Supply Department controlled the bulk of the gas and coal-tar products, commercial acids and solvents, fertilisers and certain oil seeds, oils and fats ; the Iron and Steel Production Department controlled ferrous materials, and the Non-ferrous Metals Department controlled non-ferrous metals and certain miscellaneous materials such as resin, shellac and mica, the Optical Munitions Department controlled glass and glassware materials, potassium compounds, blast furnace dust and radio-active substances ; the Aircraft Production Department controlled linen, flax, tow, and wet spun yarn, and certain forms of timber ; the Mineral Oil Production Department controlled fuel oils, creosote and turpentine ; while other sections of the Ministry controlled building and building bricks, timber, machine tools and small tools, agricultural machinery, railway material, electric power plant, motor engines and vehicles. But this parcelling out of the whole field of munitions supply was only gradually achieved, and at first centralised buying was strictly confined to a limited part of the requirements for munitions purposes.

Owing to the general reluctance of the Departments to extend their responsibilities, considerable latitude was allowed to commercial buyers until the severe tonnage shortage of the last two years of the war made it necessary for the Ministry of Munitions to extend its control, at first to buying by private firms for munitions purposes, and then to purely commercial purposes. When America came into the war, and adopted the policy of conserving the munitions materials of which it was the chief source by a strict scrutiny of all demands for them, the orders of commercial buyers had to be vouched for by the department concerned with purchase.[4] The United States showed great reluctance to supply munitions materials for British commercial demands, suspecting an attempt to prepare for post-war trade competition.

When this centralised buying was conducted by the Departments themselves and through agents appointed by them the merchants through whom the trade had formerly been conducted were eliminated,

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[1] CRV/Gen/2184 ; CRV/Gen/2186.
[2] CRV/Gen/2184 ; CRV/F/128.
[3] March, 1918 ; HIST. REC./R/1800/31.
[4] See Vol. II, Part III.

and cases of serious hardship were inevitable. Often, however, when the total quantities of the material required were not large, or technical knowledge and trade connections were of special value, the Ministry made its purchases through merchants and allowed distribution to take place through them.[1]

(*b*) Agreements with Allies.

The gradual evolution of a system by which munitions purchases for the Allies were controlled by a central organisation has already been described in detail elsewhere,[2] and it is only necessary here to draw attention to the importance of inter-Allied agreements in diminishing competition and centralising purchase. Great Britain, of course, played by far the largest part in the development of arrangements for joint purchasing. Long before any definite schemes for inter-Allied purchasing were adopted, Great Britain was buying certain non-ferrous metals for France, and until a late stage in the war, she made large purchases of iron and steel for France and the other Allies. After the summer of 1915 the bulk of the enormous Russian purchases were made by Great Britain and financed by British credit, though independent buying still disturbed the markets. The advantage of British credit and centralised buying to the Allied cause was marked. The prices quoted for orders directly negotiated by Russia were invariably higher owing to her inferior credit, and special difficulties about inspection and specifications, but France and Italy also gained largely, as the Ministry of Munitions commonly succeeded in buying at more favourable prices than they were able to obtain.

Mr. Lloyd George had frequently advocated that Allied co-operation should apply to distribution as well as purchase, that there should, in fact, be a pooling of munitions resources. During 1917 the French were strongly urging the necessity of this, but little progress was made in this direction until the last year of the war, when the Allied Maritime Transport Council and the Inter-Allied Munitions Council were formed.[3]

At the same time the principle of fixing world prices for materials, which applied to all the Allies, was adopted by America. By the end of the war the prices of the chief non-ferrous metals had been fixed, and executive bodies set up to control their distribution. Similar executives controlled the purchase and distribution of nitrate of soda and of timber.[4]

Control, therefore, which had been partial in 1916, being confined to the materials required for the war industries, was extended in 1917 to materials imported for civil industry as well, and by 1918 it had become international, and world prices were being fixed for world supplies.

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[1] This was the general policy of the Department of the Surveyor-General of Supply at the War Office in connection with wool, textiles and leather. See below pp. 125–50.

[2] See Vol. II, Part VIII.

[3] *Ibid.*

[4] The Commission Internationale d'Achats des Bois had been set up early in 1916. In 1918 a Timber Programme Committee had been constituted to regulate and secure the tonnage required for importing timber. (HIST. REC./R/1860/7; *War Cabinet Reports*, 1917 and 1918).

III. Control of Dealings and Prices.

(*a*) Control of Dealings.

The next form of control was negative and restrictive rather than stimulative; it enabled the Ministry to regulate the use of materials of which it was not the owner and to fix their prices. Regulation 30 A under the Defence of the Realm Act forbade the purchase or sale, except by licence from the Ministry, of all the materials to which it was applied, required returns of stocks and output, fixed maximum prices, and imposed conditions of sale; while Regulation 30 B prohibited speculative dealings.

Complete control involved prohibition of sale and purchase except by licence, prohibition of use except for certificated work, taking over stocks and output and scrap, the preparation of statistics of costs and production, prohibition of export, centralised buying and distribution, and control of prices. The extent of the control imposed varied with the circumstances of the case, considerable variety in the drafting of the regulations being possible. Sometimes, as in the case of tin, control never extended to the fixing of prices, sometimes the only form of control was the prohibition of speculation, as in the case of nickel, antimony, molybdenum and the ferro-alloys, or the requiring of returns, as in the case of locomotives. Sometimes, as in the case of creosote, magnesite, resin and shellac, control took the form of prohibiting use and sale for certain purposes except by licence. Second-hand material was also subjected to control (*e.g.* tools, railway material), as well as scrap, swarf and waste (*e.g.* ferrous and non-ferrous scrap, silk waste, blast furnace dust, basic slag, cinders).

As has been seen, control began with the materials for explosives. Aluminium, platinum and optical munitions were legally controlled in December, 1915, but until the middle of 1916 no great additions to the materials legally controlled had been made, control by voluntary agreement being relied upon for a time. After the summer of 1916 when shell steel was controlled, the spread of control was rapid. Other forms of steel, pig iron, iron ore and coke were controlled; machine tools, building work and most of the non-ferrous metals followed. About the end of 1916 and early in 1917 the Department extended its control to the materials for acid production, coke oven by-products, the chief solvents, glass and glassware; while the last year of the war saw a tremendous development of the sphere of control, which can be followed from the schedule of Control Orders given in Appendix I.

One of the subsidiary but still important effects of these Orders was that details of the stocks and requirements of the trade became available. This was a great help in guiding the Ministry's buying policy, in securing continuous supplies, and later, when importation had to be curtailed, in giving data to enable supplies to be fairly distributed. Occasionally these returns supplied very valuable corrections to the figures of requirements put forward as a result of general estimates, and they enabled arrangements to be made for forestalling sudden buying by the trade at unfavourable moments.

(*b*) CONTROL OF PRICES.

When the Ministry was formed, the prices of many of the chief munitions materials had already reached a scarcity level and were still rising, and the effort to reduce these prices, or at all events to prevent a further rise, was one of the keynotes of the policy of the Department in its control of materials. Costs of production were constantly increasing owing to the rising cost of labour, of freight and of coal and other stores, while another less obvious factor was the operation of the munitions levy and the excess profits duty, which made firms who had earned their standard profits much less eager to economise in production costs. They were willing, for instance, to pay high wages and very high prices for material, and competed strongly in world markets for supplies. In view of all this, the Department's success in reducing prices at the outset, keeping them at the same level throughout the war in many cases, and limiting the rise to the minimum in other cases, ranks as one of its greatest achievements.

These results were obtained by a variety of methods. Centralised buying and arrangements for limiting Allied competition enabled the Department to operate advantageously in world markets, which were also made more favourable by the elimination, under blockade pressure, of German competition. Home markets were controlled by restricting export and by taking over the whole output of munitions materials or controlling their destination, thereby constituting the Department as the chief purchaser. Restriction of import also operated to give the Ministry the monopoly of supplies and to keep prices from rising to a scarcity level. Freight arrangements and the taking over of tonnage at Blue Book rates, also worked in the same direction. The elimination of speculation by centralised buying and by Regulation 30 A under the Defence of the Realm Act had a powerful effect upon prices, which was specially apparent in connection with many non-ferrous metals and materials, the enhanced price of which was due to speculation and competition rather than scarcity, and which fell considerably when speculation was checked.[1]

Another factor in checking the rise of prices was the great increase in production obtained by setting up national factories and by stimulating extensions by the trade. Moreover, the development of the costings system, the introduction of new and improved methods of production, the installation of modern plant and labour-saving devices, and the economy of material and labour thereby achieved, all tended to reduce costs of production and to neutralise the effect of other factors tending to increase costs. Perhaps the best illustration may be found in the prices of explosives and explosives materials and propellant. Better methods of purchase, improved processes and competitive manufacture in the Ministry's factories brought about a considerable fall in prices; rising costs in some directions were set off by economies in others, and prices remained stable till the end of the war.[2]

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[1] *e.g.* aluminium, copper.

[2] See Vol. X, Part IV. The price of cordite was actually lower than in peace time.

When resisting claims for increased prices the Ministry could often demonstrate that the price originally fixed for a smaller output was sufficiently generous to cover increasing costs, when allowance was made for the economies due to large scale production for an assured market over a long period.

The price at which the output of an industry was taken over was usually a generous one in order to stimulate production. The price fixed by the Ministry for explosives materials, for instance, was commonly based on the cost of production plus six per cent., but the cost of production was calculated to allow for the amortisation over a single year of 75 per cent. of the original outlay on plant. This arrangement was considered fair in view of the fact that it was unlikely that a large proportion of the plant would have much post-war value.[1] In order to cover the costs of production of small firms prices had to be fixed at a level which sometimes allowed unreasonably big profits to large firms, but as the maximum production was needed there was no obvious way of avoiding this difficulty, which also applied to the iron and steel trades and the non-ferrous metal industry.[2]

The prices fixed by the Ministry for home products were usually governed by world prices. This was not conditioned so much by the necessity of conserving material in the country, as the export of such materials was commonly prohibited,[3] but was due to a desire to encourage output and remove a sense of grievance. There were occasional exceptions to this. Soap makers complained that the price fixed for glycerine, which was far below the world level, was quite unremunerative, but the prohibition of the importation of foreign soap gave them a monopoly which enabled them to indemnify themselves by the high prices charged to the public for soap, for the low price obtained by the Ministry for one of its by-products.

The general policy of the Ministry of Munitions in this matter was quite at variance with the policy of some of the other Allies—notably France. In England the price fixed for any material normally applied to its use for commercial purposes also, while abroad such prices were not controlled. The policy of the Ministry was due to the desire to prevent the quality of the material being graded down so that it became useless for war purposes and could command the higher prices obtainable for industrial purposes. This danger was usually guarded against by controlling the price of commercial as well as of war qualities, a notable example being commercial steel, which had to be controlled soon after the price of shell steel was controlled, in order to prevent steel makers concentrating on the production of the former where higher profits were to be obtained. The price of acid for commercial work was also fixed in order to prevent the trade from competing with the Explosives Supply Department for supplies. When such precautions were not taken the grading down process was soon at work, thus picric acid makers began to produce an excess of low quality acid in order to get the higher prices obtainable for it from commercial consumers, and dealers in mica began to grade down their product, as very high prices could be obtained for the inferior qualities,

[1] Vol. VII, Part IV, p. 9. [2] *Cf.* Supplement, p. 131. [3] See below, p. 22.

which alone could be re-exported from the United Kingdom. In order to check this leakage the Ministry made improved arrangements for grading, increased the price of the higher grades, and accepted some of the lower grades for munitions purposes.[1]

In fixing the prices at which the whole output of a firm or of the trade was taken over, therefore, there had to be a nice balancing between too high a price, which would have a cumulative effect on munitions contracts, and too low a price, which would fail to encourage production or put a premium on leakage to industrial uses. But in certain very important cases the operation of all these factors was insufficient to balance the natural increase in the cost of production, and the Ministry had to choose between increasing the maximum prices allowed, or accepting a decline in production. The latter course was impossible and the former had many drawbacks. The policy of giving a subsidy to the industry to meet increased costs of production was therefore adopted in certain cases, of which by far the most important was the steel and iron industry.[2] The ramifications of the subsidy system have been considered in detail elsewhere,[3] together with the question whether the advantages of keeping prices fixed and thereby minimising alterations in munitions contracts and in wages (which were governed by sliding scales varying with the price of the product), compensated for the disadvantages of putting one of the chief industries of the country upon an artificial basis, which militated against its post-war position. As long as the war lasted the disadvantages were probably outweighed by certain obvious advantages—the maintenance of an unvarying maximum price and the minimum disturbance of labour (though towards the end of the period part of the subsidy was included in the price for the purpose of calculating wages). Moreover, the argument that Allied Governments and industrial consumers were buying steel at artificially low prices, only rendered possible by the fact that the British Government was subsidising the industry, was met by the decision to add the estimated amount of the subsidy to the price charged to the Allies, and by the fact that the amount of steel that was being released for non-Government purposes only amounted to an insignificant fraction of the whole. But it was obvious that with the return of peace conditions these arguments would fall to the ground. Steel actually cost about £10 a ton more to produce than the price at which it was being sold, and the Ministry decided that the subsidy system was a vicious one which must be abandoned as soon as possible. Subsidies were therefore withdrawn in two stages, their immediate withdrawal being considered inexpedient in view of the dislocation in trade that would be caused by an immediate addition of some £10 to the price of a ton of steel, and by the labour demands which might be expected to follow such a large increase in price.

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[1] For details see Vol. VII, Part III ; Vol. VII, Part IV.

[2] Other examples are the bonus given to spelter refiners to meet the cost of imported calamines, and the subsidy (based on a sliding scale under which profits decreased with increased costs of production) introduced to stimulate the production of pig iron.

[3] Vol. VII, Part II.

The competition of subsidised with non-subsidised materials was unfair, but it occurred but rarely. An illustration is the freight subsidy on Spanish manganese ore (really an iron ore) which competed with Indian manganese ores which had to pay the ordinary freight. The Ministry pointed out, however, that the price of the latter material was not controlled like that of the former.[1]

IV. Restrictions on Export and Import.

(*a*) General Policy.

By the methods outlined in the preceding paragraphs the Ministry of Munitions was able to secure the output of certain important industries at fixed prices. Side by side with this went another form of control, the restriction of the export or import of certain commodities in order to conserve war materials for war uses, to economise tonnage or to prevent capital, labour and machinery being absorbed in the production of goods not necessary for war purposes.

Restriction of export or import (of which the former was by far the most important) involved, of course, many hardships to traders, and this part of the policy of the Government was strongly criticised. The necessity for restriction was admitted by everyone, but every trade and interest protested against its operation in particular cases. Moreover, several Government Departments, the Admiralty, the Foreign Office, the Board of Trade, as well as the Ministry of Munitions and the War Office, and later the Food and Shipping Controllers, were deeply interested in one way or another in the control of export or import. It was sometimes difficult and occasionally impossible to reconcile the aims of these Departments, and the whole question was complicated by diplomatic difficulties. Frequently a working compromise which satisfied no one had to be adopted.

The main object of the various bodies who controlled trade during the war was to protect the supplies required in the United Kingdom, whether for civilian consumption or the effective prosecution of the war, and to harm the enemy as much as possible without extinguishing British trade. At the outset, trading with the enemy was forbidden by a series of Proclamations,[2] and long lists of goods and stores the export of which was prohibited on the advice of the Board of Trade or one or other of the War Departments were drawn up. Proclamations prohibiting import were issued on a smaller scale. But almost at once this absolute embargo was broken down by the growth of a system of licences under which prohibited goods could be exported to approved destinations, such licences being issued at first by the Privy Council and later by the Board of Trade on the recommendation of an interdepartmental Committee on Trading with the Enemy, which represented the Treasury, Home Office, Foreign Office, Admiralty, War Office, Colonial Office, India Office, Board of Trade, Customs and

[1] CRV/E/120 ; CRV/S/598.

[2] A provisional list of articles of which export should be prohibited on the ground that supplies were insufficient for War Office or naval requirements was in existence when the war broke out. For later lists see CRV/Gen/1545.

Excise and Privy Council Office[1]. The first export licence of the war authorised the export of canteen supplies to Gibraltar (12 August), the first import licence allowed the importation of aniline dyes of German origin (28 August, 1914).

In view of the fact that the Ministry of Munitions was later so deeply interested in this licensing system, it is important to recapitulate here the general principles which governed its development.

> " In authorising or prohibiting particular transactions with the enemy the Committee was guided by considerations of commonsense. Its main object was to ascertain whether on the balance the proposed transaction would benefit this country more than the enemy, and whether the advantage to be gained was so considerable as to warrant a departure from the rules laid down by the emergency proclamations. Thus, in exceptional cases, the Committee allowed the importation of goods of enemy origin provided they were urgently required and could not be obtained from other sources. The ultimate responsibility for Proclamations and Orders dealing with prohibited and restricted exports belonged to the Board of Trade, which acted partly on its own initiative, partly on representations from the War Office, the Admiralty and other Departments concerned. Applications regarding each particular commodity were scrutinised in the first instance by the representative of the Department at whose request the export of that commodity had been prohibited. In the first place it was necessary to ascertain whether there was an actual or apprehended shortage in the United Kingdom of the commodity in question ; if the application was one for leave to export to a neutral country the question arose whether that country had issued an effective prohibition against re-export, and whether the neutral purchaser offered a sufficient guarantee against re-exportation to the enemy. If a competent authority held that the commodity to be exported was one of supreme value to the enemy, the tendency was to refuse to let it be exported to any destination in neutral Europe. If, on the other hand, the commodity was held to be relatively unimportant to the enemy, the Committee was often urged to issue a licence without insisting too meticulously upon guarantees, for the sake of promoting British export trade."[2]

Early in 1915, owing to pressure of work and consequent delays, the licensing organisation was strengthened, and a new Department, the War Trade Department, which absorbed the licensing work of the Committee on Trading with the Enemy, was set up. On the main licensing committee of this Department, which dealt with all questions of principle, the Ministry of Munitions was, of course, represented. A special sub-committee for iron and steel was appointed to deal with the paramount interests of the Ministry, which was also specially concerned in the work of the Copper Sub-Committee, the Rubber and Tin Exports Committee, the Oil and Fats Committee, the Black List Committee and the Admiralty Sub-Committee, which controlled the

[1] Carless Davis, *History of the Blockade*, p. 115 (Copy in HIST. REC./R/600/25).
[2] *History of the Blockade*, pp. 117, 118, 121.

export of commodities as miscellaneous as ferro-alloys, manganese, jute, rock crystal and olive oil, and the War Office Sub-Committee, which dealt with telephone and telegraph apparatus, electrical apparatus, tin and terneplate, varnish and range-finders.

The practice of referring to the Ministry of Munitions all applications for licences to export goods controlled by the Department was gradually evolved.[1] Goods for export were divided into two lists. Nothing included in the A list could be exported without a licence, and everything on B list could be exported without licence to British possessions and Allied countries, export to other destinations requiring a licence. The working of this system revealed certain anomalies. Machinery was not originally included in either list, and could therefore be exported without licence to any destination except actually to the countries adjacent to the enemy, though after the inclusion of mild steel in the A list, no class of unmanufactured steel could be exported without licence. Thus, while the export of a single steel sheet was prohibited without licence (which was only granted by the War Trade Department on production of a contract reference number from the Admiralty, War Office or Ministry of Munitions), when sheets were put together into a boiler, no licence was required for export. In the same way the War Trade Department sanctioned the export of machinery containing steel, brass or copper, except in special cases when an ultimate enemy destination was suspected, though the export of the unmanufactured metals was prohibited[2]. Inconsistencies of this kind were due, of course, to the fact that so many Government Departments were concerned in the matter, and that no general principles to guide decisions existed when the war broke out.

As the war went on restrictions on both export and import became more stringent, owing to the increased scarcity of materials, shortage of tonnage and the tightening of the blockade. But in the last year of the war a strong reaction against this stringency, which was thought to be pressing with unnecessary weight upon British trade and financial stability, is discernible, this point of view being championed by the Overseas Trade Department and the Colonial Office.[3]

Obviously, the chief ground upon which the Ministry asked for the prohibition of export of munitions materials was in order to conserve stocks for war work. The prohibition of the export of toluol and benzol and certain other coal tar derivatives early in August, 1914 is one of the first examples of this, and as other materials became scarce their export was forbidden by Proclamation issued on the authority of the Board of Trade, at the request of the War Office and later of the Ministry of Munitions.

Care had to be taken that these embargoes did not hamper the manufacture of munitions by Allied or neutral Governments. Thus in the summer of 1915 there were complaints from munition-makers in the United States that the embargo on the export of glycerine from Great Britain was causing serious difficulties ; they urged that sufficient

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[1] CRV/Gen/0543.
[2] Minutes of Priority Advisory Committee. 4 April, 1917 (CRV/Gen/1545).
[3] See below, pp. 29, 99, 100.

glycerine for the manufacture of explosives for the British Government should be allowed, subject to a guarantee that it would not be used for any other purpose. Owing to the shortage in Great Britain export could not be allowed, but fortunately it was discovered on investigation that the chief manufacturers of cordite in the United States had already secured enough glycerine to fill their contracts.[1] About the same time the prohibition of the export of tungsten and of platinum was also causing anxiety in America.[2] On the other hand, the Ministry could not view without alarm the supply of scarce munitions materials to the Allies, since there was no security that they would not be used for commercial purposes.[3] There was special difficulty about the iron and steel supplied to France, as until the middle of 1917 it was sold at the nominal price, without taking the subsidy into account, and, in any event it had to be replaced by material bought in America at higher prices.

A similar control of export and import was exercised throughout the British Empire, the necessary steps being taken through the India Office or Colonial Office, as the case might be, on the request of the Ministry of Munitions. Thus the export of steel and the chief non-ferrous metals and explosives materials from British possessions (except to British destinations) was prohibited or permitted only by licence, and these restrictions formed an important link in the policy of conserving and developing Imperial resources for munitions production of which more will be said in a later chapter.

The promise to allow licences for export from British Dominions was sometimes a valuable diplomatic counter; negotiations with the American Aluminium Company, for instance, were facilitated by the promise to allow the export of bauxite from British Guiana,[4] while British control over the export of tin, nickel and graphite was found specially useful.[5] Occasionally the prohibition of export was used as a lever for obtaining concessions, as when the export of aluminium from Canada except to the United Kingdom was prohibited, with the result that better terms were obtained from the American Aluminium Corporation who were depending for some of their contracts on supplies from their Canadian subsidiary.

When the United States came into the war Canada was placed in a special position. In order to prevent the evasion of United States' regulations prohibiting export of war materials and import of non-essential materials in order to economise shipping, Canada adopted the same policy, and the Canada Gazette of 3 August, 1918, contained a long list of war materials ranging from acetate of cellulose to zinc oxide, that could only be exported by licence from the War

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[1] 30 July–10 Sept., 1915. (L. 6599, 6842, 8070, 8134, N.Y. 5782, 5901, 5998, 7276, 7420).

[2] 30 September, 1915. (L. 8626).

[3] *e.g.*, rubber (A.S. 11809/1918), nickel and copper.

[4] See Vol. VII, Part III, Chap. V.

[5] The United States wanted to secure a definite proportion of the tin produced in the Straits Settlements, and a delimitation of markets. The allocation of tin was a matter of great difficulty, complicated by international suspicions. (CRV/U/162, 208, 236, 279).

Trade Board of the United States, and another list of commodities ranging from agricultural implements to quebracho wood which required licence for importation.

The usual grounds on which the Ministry advised the refusal of import were that the proposed importations were not essential (*e.g.*, mattress wire and electric motors), or that a sufficient stock already existed in the country (*e.g.*, antimony),[1] policy in the latter case being influenced by the fact that the Ministry wished to market its stocks without loss. Later, the Ministry often requested the Board of Trade to refuse licences for importation in order to prevent private buyers from competing with the Ministry in foreign markets. Later still, in 1917 and 1918, the most rigid restriction of importation became necessary in order to economise shipping and exchange. In 1917 the Ministry urged that French policy should be followed, and the import of all luxuries and superfluities prohibited to economise exchange,[2] while in the last year of the war there was little scope for further departmental action in this direction, the ground being covered by Cabinet decisions, and imports, both departmental and private, being limited to actual necessities. Pressure of necessity therefore squeezed out the private importer, and rendered the Ministry's monopoly of the materials it controlled complete.[3]

(*b*) The Effect of Blockade Restrictions.

As has been seen, the advice of the Ministry of Munitions usually determined the action of the Board of Trade in issuing or withholding licences for the export of munitions material. But certain cases involved a conflict of interest between the Foreign Office, the Ministry of Blockade and the Ministry of Munitions. In order to shut out materials from Germany the Admiralty and the Foreign Office had to keep a close watch on the imports of those neutral countries from whom munitions materials or their equivalents might be re-exported to Germany. The policy of "rationing" Border neutrals—restricting their imports to their pre-war average with a certain margin—was generally adopted from July 1916 onwards,[4] and though it was naturally unpopular with neutrals some success was achieved. Agreements on this rationing basis were reached with Holland, Switzerland and Denmark before the end of 1915,[5] and the fact that Norway was almost entirely dependent on British coal made a fairly efficient system of rationing possible in this case also, though Norwegian firms with German affiliations continued to be a source of considerable anxiety.

But Sweden was a different and difficult problem. German influences were strong, and Great Britain was dangerously dependent

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[1] CRV/Gen/1692 ; D.D.G.M. 1087 ; See also Vol. VII, Part III, Chap. IX.

[2] CRV/F/016.

[3] The restrictions on the importation of rubber in 1918 aroused violent protests from the trade. (CRV/Gen/0609, 0527).

[4] *History of the Blockade*, p. 16.

[5] *Ibid.* p. 17. Special care had to be taken that materials and machinery supplied to Swiss contractors who had taken British orders for munitions were not used for the benefit of the enemy.

upon Sweden both for the maintenance of the transit trade with Russia and for the supply of certain materials, of which ball bearings, special irons and iron ores, gauges and timber for pit props were the most important. As the Ministry of Munitions was specially interested in these Swedish supplies,[1] the Department exercised all its influence in favour of allowing Sweden to import the raw materials and machinery which she required as an equivalent for her munitions exports, and was constantly pressing the Admiralty and Foreign Office not to make the blockade too stringent. The Foreign Office, however, suspected that some of this material got through to Germany, in spite of guarantees by importers against re-export.[2] It proposed that Sweden should be rationed in certain commodities, insisted on reviewing each request for licences on its merits, and urged the Ministry to emancipate itself from its dependence on Swedish supplies.[3] Substitutes were found for certain of these supplies,[4] but the dependence upon Swedish ball bearings actually increased owing to the development of the war in the air,[5] and in 1916 and 1917 Swedish ball bearings represented one-third of the requirements for the aircraft programme.

Friction with Sweden increased during 1916, and the Foreign Office became still more urgent that the Ministry should "emancipate itself and cease to be a millstone round the neck of the Foreign Office" (July 1917). The Foreign Office contended with some reason that British exports of steel, machinery, lubricating oil, ferro-manganese, etc., to Sweden constituted a breach in their general blockade policy, but had to condone it in view of the value of Swedish supplies and the need for maintaining the transit trade with Russia. The export of ferro-manganese was a special difficulty, as it enabled Sweden to increase her export of ferro-alloys to Germany, but the Ministry contended that the exports to Germany were a low grade spiegel iron and that the ferro-silicon exported to Great Britain in exchange for ferro-manganese was vital to certain classes of steel manufacture. Prolonged discussion resulted in the prohibition of export to all companies who were proved to be trading with Germany on any considerable scale (21 May 1917–January 1918).[6]

The entry of America into the war and the defection of Russia strengthened the position of Great Britain with regard to Scandinavia and in the autumn of 1917 a determined attempt was made to check Sweden's export of munitions and munitions materials to Germany, especially iron ore, and Norway's exports of nickel, pyrites, molybdenite, ferro-silicon and mica, which were going on on a very large scale.[7] The adoption by the United States of a policy

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[1] Ministry of Munitions to Foreign Office 15 February 1916. (CRV/S/059, 060).

[2] December 1915 (CRV/S/059).

[3] 19 July 1916 (CRV/S/070).

[4] *e.g.*, steel made in electric furnaces was used instead of Swedish steel; Swedish spelter, perchlorate of ammonia, blow lamps, etc., were also dispensed with.

[5] CRV/S/070, 0149, 0374.

[6] CRV/S/0374. For details see HIST. REC./H/1810/6, CRV/S/05, 041, 082, 0154, 0156, 0166, 0336, 0392, 0447.

[7] Conference with Foreign Office, 25 July 1917 (CRV/S/0374).

of general embargo, which prohibited all exports to Scandinavia and Holland except by licence, was followed by similar action by Great Britain and France, a Proclamation being issued on 9 September 1917.[1] The United States was anxious to cut off from the northern neutrals all supplies which might be useful to Germany, and the Foreign Office was prepared to face the consequences of a drastic embargo. The Ministry of Munitions, however, contended that the consequential loss of Swedish supplies would make this policy injurious to the Allied cause. The Swedish trade that was really vital to Germany, the iron ore trade, could only be cut off by naval action in the Baltic ; and it could not be stopped by any form of diplomatic or blockade pressure.[2]

Important supplies from Norway and Holland, as well as Sweden, would be threatened if retaliatory measures were adopted, notably iron ore, aluminium, spelter, nickel steel, calcium carbide and ferro-chrome from Norway,[3] and Borneo petroleum for conversion into toluol from the Dutch East Indies. Moreover, the withdrawal of Swedish, Norwegian and Dutch shipping from the general shipping pool available for the Allies would be serious.[4] The Ministry therefore urged that all supplies both from the United States and from the United Kingdom vital to Scandinavian firms producing munitions should be licensed, and that the United States Government should not insist on a guarantee that the goods exported would not be used in the manufacture of stores for Germany, as in the case of certain Swedish firms the British Government had been obliged, as a condition of supply, to export ferro-manganese, abrasives and lubricants without obtaining such a guarantee.[5] This view was combated by the Restriction of Enemy Supplies Department on the ground that the whole position had been changed by the entry of the United States into the war, which gave the Allies a practical monopoly of world supplies and enabled them to take a much firmer line with the Scandinavian neutrals, while the possibility that Sweden would stop the transit trade with Russia lost its importance with the increasing demoralisation of Russia.

Some hundreds of Swedish firms were still, at the end of 1917, obtaining engineering supplies and lubricating oil from the Allies ; while Sweden was actually still exporting lubricating oil to Germany. At a conference on 20 October 1917 the Ministry agreed that a more stringent line must be taken, and that the supply departments must be pressed to render themselves less dependent on Swedish supplies, and must support every application for leave to export by a statement showing that the demand was reasonable. It was impossible to obtain, as the Foriegn Office wished, a *quid pro quo* in each case, as some of these supplies were of a general character and the manufacturing results could not be specified.[6] No further contracts for Swedish steel and iron were to be placed, but in view of the favourable price, existing contracts were to be completed (4 December 1917). The Ministry

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[1] *History of the Blockade*, p. 21. [2] CRV/U/0156.

[3] The French were also interested in Norwegian supplies of ammonium nitrate, (CRV/N/0177).

[4] CRV/U/0156. [5] *Ibid.* [6] CRV/U/0182.

also suggested to the Treasury that private firms should be instructed not to place any such contracts without the sanction of the Ministry,[1] such sanction being normally refused owing to the unfavourable exchange, and the Treasury agreed (13 December).

In the last year of the war, the Foreign Office concentrated on cutting off coal, steel, machinery, electrodes, etc., from those firms who were exporting to Germany on a considerable scale.[2] This led to protests from the Ministry of Munitions, as it affected firms supplying them with large quantities of ball bearings and gauges. Each case involved a considerable amount of interdepartmental discussion, and no satisfactory compromise had been found at the date of the Armistice.[3]

Relations with Norway were much less difficult. The Ministry helped British iron ore companies in Norway by pressing the Foreign Office to facilitate shipments of machinery from the United States,[4] and after the agreement with Norway reached in the summer of 1918, which resulted in raising the blockade of Norway, the Ministry of Munitions was no longer required to obtain a *quid pro quo* for the goods exported.[5] Moreover, efforts were made to supply steel for Norwegian ship-building.[6]

It was desirable, for many reasons, to conciliate Dutch opinion, and on the request of the Foreign Office, licences were issued for the export of certain brass, copper and nickel goods, subject to guarantees against re-export to Germany.[7] The Dutch situation was complicated by the desire of the British and American Governments to secure that the stores sent through Holland for Belgian relief did not find their way to the enemy, and by the difficulty of providing that Holland was only allowed to import sufficient oils and fats for the manufacture of margarine for the British Government,[8] and for the soap and candle trade. The danger of oil and fat getting through to Germany was compensated for by an agreement under which the Dutch supplied one ton of glycerine to Great Britain for every 15 tons of soap exported to Germany.[9]

The Ministry of Munitions constantly urged the necessity of maintaining export trade to neutrals, and, by the end of 1917, it was clear that the Foreign Office had considerably modified their views with regard to the "strict blockade" policy.[10] Repeated protests were received from H.M. Ministers in the Scandinavian countries pointing out that as British exports to those countries declined Germany was becoming more and more active, with a marked effect upon the exchange. Home industries were being curtailed by the prohibition of export, while neutral countries were being drawn closer to the enemy. The chance of mitigating the stringency of the export prohibition policy—especially

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[1] Though Swedish prices were very high this did not check the anxiety of British firms to buy, owing to the operation of the excess profits duty (CRV/U/0156).

[2] CRV/U/0156.

[3] For further details, see HIST. REC./H/1000/6.

[4] Dunderland Iron Ore Company, April 1918 (CRV/M/170).

[5] CRV/Gen/0153. [6] CRV/N/0168, 0195. [7] CRV/H/87, 230.

[8] *e.g.*, Foreign Office telegram to Washington 6 October, 1917, (CRV/U/0156).

[9] 74/Holland/11. [10] CRV/Gen/0147.

with regard to the export of expensive articles of luxury, and of commodities which the Germans were themselves exporting to neutrals—was increased by a change of attitude on the part of the United States Government which, by the end of 1917, was becoming conscious that the strict blockade of the northern neutrals upon which it had insisted had a detrimental effect on the future of American trade.

But though the United States Government now agreed with the general principle of mitigating the severity of the blockade, it at first limited the concession to Sweden and Holland, which had just agreed upon a *modus vivendi* with the Allied Governments, and in February 1918 a list of articles exempted from the general embargo on export to Holland and Sweden was issued. The list was extended after a further conference on 22 March 1918,[1] and applied to Norway on the signature of a commercial agreement with her in June.[2]

But there was another side to the picture. Owing to the shortage of labour and material, most of the energy absorbed in manufacturing goods for export would be withdrawn from munition or other necessary work, and by the time a mitigation of export restrictions was deemed to be desirable, the shortage was so acute that such diversion could only be allowed on a very small scale, and in cases where labour and capacity could not be readily transferred to munitions production. The chief effect, then, of this change in the attitude of the Foreign Office and the United States was that the Ministry slackened its efforts to make itself entirely independent of Scandinavian supplies,[3] its policy being to set up alternative sources of supply in Great Britain on a commercial scale capable in emergency of expansion, thus freeing the country from the dangers of total dependence on a foreign source, while at the same time continuing to give orders in Scandinavia on a sufficient scale to occupy the works which had been extended or equipped with British help, and prevent them from undertaking work for the enemy on a considerable scale.[4] The Foreign Office, however, insisted that no supplies should be forwarded by the Ministry of Munitions to Swedish firms working for it except under a guarantee, in accordance with the terms of the Swedish agreement.[5]

(*c*) Blockade Purchases.

In order to realise the objects of the blockade the Foreign Office adopted in 1916 the policy of buying from neutrals commodities which would otherwise have been sold by them to Germany.[6] An illustration of this blockade purchase policy affecting the Ministry of Munitions may be found in the negotiations for the purchase of the output of the Sydvaranger mine in Norway, in order to cut off their

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[1] CRV/Gen/0417. [2] CRV/Gen/0155.

[3] Especially of ball bearings, screw gauges and measuring slips (CRV/Gen/0417).

[4] The whole policy is discussed in connection with the supply of machinery from British sources to a Swedish firm in February 1918, (CRV/Gen/0417; CRV/S/0462; CRV/U/0156).

[5] July 1918, (CRV/Gen/0543).

[6] *History of the Blockade*, pp. 18, 19.

trade in iron ore concentrates with Germany. The case was a complicated one.[1] The Ministry wanted briquettes but not concentrates, and to secure the former had to supply machinery for their manufacture, hitherto obtained from Germany. When, however, evidence was forthcoming that the company's exports to Germany were increasing and its output of briquettes was diminishing, the Ministry refused to support its application for licences to import machinery, as it appeared that the increased output would primarily benefit the enemy. The briquettes, though valuable for munition purposes, especially for the production of high grade Admiralty steel, were not absolutely indispensable (10 July 1917). Supplies of coal and machinery were therefore cut off and the firm was placed on the Black List (22 November 1917). Under this pressure the firm became more compliant. It offered to limit its trade with Germany to existing stocks in return for removal from the Black List (July 1918), but this was not authorised until December, when the war was over.

Another suggested blockade purchase was that of scrap copper from Holland (November 1916). The Ministry thought the price high, but was willing to buy if the Foreign Office thought it desirable that it should not pass into the hands of the enemy. (It was free of the Netherlands Overseas Trust conditions as it was already in Holland). As a loss of £30,000 would be incurred, and much larger purchases would have to be made in order to prevent the possibility of any of this scrap material being smuggled into Germany, export, except on a very small scale, being prohibited by the Dutch Government, the Restriction of Enemy Supplies Department did not think the purchase would be justified (14 November 1916).[2]

Figures showing that this scrap metal traffic was being kept within the limits agreed upon were furnished monthly to the British Government, but it was felt that this trade and the large trade with Germany in scrap iron needed careful watching. The Ministry of Munitions was anxious to obtain high-class scrap iron from Holland, but little scrap iron was exported to the Allies.[3] Prolonged negotiations followed, and the question was not settled until the economic agreement of November 1918 was signed. By this time, however, scrap metal was no longer required.

The Foreign Office also thought it possible that the Ministry of Munitions would buy some of the assets of the Northern Exploration Company in Spitzbergen, in order to prevent the company selling them to Norwegian or Swedish purchasers, but the Ministry declined (15 May 1916), as it appeared unlikely that supplies of iron ore and coal would be available in less than two or three years,[4] and later refused to assist a powerfully supported scheme for dispatching an expedition to survey and report on the deposits, as the development of new sources of supply was of less importance than the securing of tonnage to transport supplies from more accessible sources.

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[1] For further details, see HIST. REC./H/1810/2 ; CRV/N/037, 038, 039.
[2] CRV/H/87. [3] CRV/H/230, 340. [4] CRV/N/03.

Occasionally, the Ministry advocated a blockade purchase, as in the case of Norwegian pyrites. Germany had offered a very high price for this material to be held in store, and as it was vital to the manufacture of sulphuric acid, both for explosives and food production, the Ministry appealed to the War Cabinet to allow a purchase for which sanction had been refused by the Treasury, owing to its high price. This purchase was supported by the Minister of Blockade and also by the Admiralty and the Foreign Office, as it would relieve our total dependence on Spain, as well as economising tonnage on a very dangerous voyage and preventing supplies passing to Germany, and on 6 May the War Cabinet sanctioned the proposal.

V. Control of Distribution

Having secured supplies of materials, the Ministry's next problem was that of distribution. This form of activity began, of course, with the distribution of explosives materials to manufacturers, and received a great impetus when the Ministry began supplying, at first its own factories and co-operative groups, and later other munition makers with the chief munition metals. Gradually this control of distribution was extended to subsidiary materials essential for munitions production, and finally, in the last year of the war, the whole stocks of materials controlled by the Ministry were distributed by it according to priority principles, munitions works and other necessary industry coming first, and any residue being allocated to less essential trades.[1]

The actual machinery of distribution worked well, and the chief complaints were of insufficient or poor quality supply, not of departmental errors, while the better transport facilities enjoyed by Government material enabled the speed of distribution by the Ministry to compare favourably with distribution through trade channels. In most cases the machinery of distribution was arranged by the supply departments of the Ministry, and the cases in which distribution was carried out otherwise were few and unimportant, the chief being the rationing of non-essential trades through their own organisations or through chartered accountants. In a few other cases, *e.g.*, petroleum, platinum, resin, emery stone, distribution was entrusted by the Ministry to an individual trader or trade association.

As the Ministry acquired manufacturing experience, this distribution of materials to munitions works enabled it to secure considerable economies which will be referred to below ; firms who obtained supplies of material were required to use it economically, and the practice of competent firms and of national factories became the standard ; firms who wasted material were penalised by diminishing their supplies ; the control of scrap and waste became stricter, and by the end of the war the Ministry was in a position to insist that a certain proportion of scrap or waste should be returned or accounted for when new material was issued.

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[1] See below, Chap. IV.

The issue of Government materials to contractors provided the Ministry with one of its most difficult financial problems. The method of free issues involved the danger of waste and fraud, but these dangers diminished as the Ministry acquired experience of the amount of material consumed in the various processes and as the control of scrap and waste became stricter. Further, the accounting methods in force during the first two years of the Ministry's existence were insufficient to secure a complete record of free issues, and in spite of later reforms, the value of a proportion of the material issued was never recovered, and this leakage had to be recognised in some of the financial settlements arrived at after the Armistice. The method of issuing materials at a fixed price was not without its difficulties; prices could not follow market fluctations closely owing to the accountancy problems involved, but if there was a wide gap between issue prices and market prices there was a temptation to sell the Ministry material to the trade and to produce too high a percentage of scrap.

CHAPTER III.

DEVELOPMENT OF NEW SOURCES OF SUPPLY.

I. Review of Industrial Developments.

Owing to the fact that Great Britain had never envisaged a land war on the enormous scale of the war of 1914 to 1918, certain industries vital to large scale munitions production were entirely lacking, while others existed only on a small scale or were under enemy control. For the products of these industries before the war Great Britain had relied upon Germany and Central Europe. The cutting off of this source of supply presented a problem which became acute as existing stocks were used up. In some cases (*e.g.*, drugs and hosiery needles) the shortage was so serious at the outset, that licences to import from the enemy actually had to be issued, but, speaking generally, it was not until the end of the first year of the war that the problem of renewing depleted stocks by developing home industries to take the place of supplies formerly obtained from Central Europe was seriously faced. To this general statement the work of the Explosives Supply Committee forms an exception, as during the first twelve months of the war it had to adopt measures for relieving the shortage of materials for explosives manufacture by developing their production at home. But, apart from this, little was done to find new sources of supply during the first year of the war. The Ministry of Munitions, therefore had to continue the development of the coal-tar industry and to develop or set up certain industries subsidiary to and essential for munitions production, the chief of which were the refining of certain non-ferrous metals (chiefly zinc, copper, aluminium, nickel and antimony), the production of synthetic cryolite, the manufacture of optical instruments, optical and chemical glass, glass bottles, etc., and the manufacture of electrical machinery, the large scale production of chemicals for gas warfare, and the development from very small beginnings, of the aircraft and aero-engine industry.

Further, in order to meet the pressure for supply, the Ministry had to bring about a vast expansion even of a long established and powerful industry like the iron and steel industry, which also had to be induced, under pressure of shipping difficulties, to transform a considerable proportion of its processes in order to utilise native ores more fully.[1] Among the existing industries which were prevailed upon, by pressure and financial help, to adopt new processes or to develop well known processes which promised an increased output of munitions materials, the chief, from the point of view of its importance and the scale in which it was developed was the alteration in the manufacturing methods

[1] See Vol. VII, Part II. The introduction of new processes is summarised below in Chapter VI.

employed by gas companies and in the coke oven industry in order to recover toluol, benzol and phenol.[1] Other new processes which are referred to in more detail elsewhere were those for the production of alcohol from grain, for the production of synthetic phenol, various fat-splitting processes for glycerine recovery, the development of wood distillation, various new methods of potash recovery, of which the chief was the recovery of potash from blast furnace dust, the distilling of fuel oil from cannel coal, and finally the adoption during the last year of the war of a process for fixing atmospheric nitrogen on a very large scale, though the scheme was only in its initial stages when the war ended.

In order to develop the supply of aircraft, new industries were set up and existing ones developed to an extraordinary extent.

> "Aircraft construction was in its infancy in 1914 and the aero-engine building industry was practically non-existent. . . . At the end of the war aero-engine production was a huge industry involving innumerable firms of small and large capacity, and British engines had outstripped the productions of all other countries in reliability and efficiency."

The advances made by subsidiary industries were remarkable. The production of magnetos was multiplied one hundredfold ; the research on alloy and steels, the development of strong light-weight metal tubing, and of petrol resisting rubber tubing, and the improvement in the quality of oil and petrol are all of permanent value to industry.[2]

The Irish linen industry was developed to meet the demand for aeroplane fabric. The whole of the Irish flax crop was taken over in 1917 and distributed to spinners at fixed prices, and from the beginning of 1918 the whole spinning industry was controlled, great improvements in the scutching process being introduced in order to save flax. Scotch manufacturers were also induced to make the class of linen required by the Department, and the rate of production in 1918 was seven times as great as in 1917. Flax seed was taken over and growth in Canada, Japan and elsewhere encouraged, with the result that it was possible, after the Armistice, to supply Belgium, France and Serbia with their requirements for reconstructing their flax industries.[3]

Among the other considerable industries which were developed by the Ministry of Munitions were the manufacture of ferro-chrome, tungsten powder and ferro-tungsten, carborundum, electrodes and magnesite bricks, which had either not existed at all in this country or had been of negligible importance. The manufacture of wire rods and wire was another of the industries which was greatly developed in order to make good the supplies formerly obtained from Germany and Belgium, this material being essential in the manufacture of cables, wire rope, barbed wire and other fencing, springs, textile machinery, nails and screws, pins and needles, and in minor but still considerable trades

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[1] The organisation of the chemical industry to supply high explosives and propellant was a great achievement, since in this trade the enemy was pre-eminent and the resources of Great Britain were undeveloped. For details see Vol. VII, Part IV and Vol. X, Part IV.

[2] Vol. XII, Part I, Chaps. IV, VII.

[3] Vol. XII, Part I, Chap. V.

like brushmaking and piano-making. At first wire rod and wire had to be imported from the United States and Canada, and it was not until the beginning of 1918 that it became possible to prohibit the importation of wire in order to save dollars and tonnage. After this prohibition it became very difficult to meet the demand even for direct war work,[1] and the multitude of less essential trades using wire were kept alive by a ration of the defective wire inevitably produced in process of manufacture, which also had to be strictly controlled to prevent the familiar grading down process.

These efforts to establish new industries and develop new processes were not confined to the United Kingdom. Similar schemes were set on foot throughout the Empire wherever a favourable opportunity presented itself, though the extent to which these developments were directly due to Ministry activities, naturally varied. Thus, the development of steel production in India, and of copper and zinc refining in Canada owed but little, financially at all events, to the Ministry, though they sprang directly from the demands for munitions production. On the other hand the development of zinc refining in Australia was based upon a long term contract with the British Government, which covered a period of years after the war. Mica production in India was stimulated by the Ministry and the Indian Government working in close touch with each other, and the production of platinum in British Columbia was encouraged by permission to raise capital and by priority concessions for necessary plant. Corundum deposits in the Transvaal were developed and assistance was given to railway construction in India, and rolling stock was supplied in Rhodesia in order to improve the output of chrome ore. The production of bismuth in South Africa and Australia, of cobalt in Canada, and the refining of saltpetre in India were also encouraged.

II. Exploitation of Mineral Resources.

(*a*) Ferrous Minerals.

In addition to developing new industries, the Ministry had ultimately to try to develop the ore resources both of the United Kingdom and of the Empire. Great efforts were made to increase output from the mines and quarries of Great Britain, but most of these schemes belong to the last two years of the war, when the loss of shipping forced the Ministry to embark on enterprises which, from the financial point of view, promised only a small or speculative return. Moreover, even such of the schemes as might have had fair prospects of success in normal times, resulted in comparative failure owing to the shortage of steel, of man power and of coal. The shortage of labour was one of the chief obstacles throughout, and some considerable and expensive housing schemes were undertaken to provide for prisoner labour and labour imported from a distance to work mines or quarries (*e.g.*, dolomite quarries and iron ore mines).

[1] The Army in Mesopotamia was using huge quantities of wire netting for road making, and aviation demands had also greatly increased.

In order to economise some of the tonnage required for the transport of Spanish ores, which represented one half of the total importation for munitions purposes, efforts were made to increase the output of hematite ores within the United Kingdom, both by guaranteeing the profits of the mine owners, and by supplying outside labour. Finally, as has been seen elsewhere, the Ministry took over certain mines in Cumberland under the Defence of the Realm Act. This venture was not a financial success when the ore produced was reckoned at the controlled price, but it replaced Spanish ore, the landed cost of which was much higher, while every ton produced economised shipping.[1]

Much more success was attained in developing the output of phosphoric ores. Transport conditions were improved by supplying more railway wagons for the ore traffic, while a railway was built to open up the Oxfordshire iron field. Labour difficulties were surmounted by forming prisoners' camps in various districts, and the output of ore outran the capacity of the blast furnaces, though that was being rapidly increased.[2]

Among other developments, which are recorded in later volumes, and can only be referred to here, were the quarrying of shales for oil production,[3] the use of British deposits of sand for glass making,[4] and boring for petroleum.[5] Mining for non-ferrous minerals, which is not dealt with elsewhere, is treated in more detail below.

(*b*) NON-FERROUS MINERALS.[6]

The production of non-ferrous minerals (excluding coal) in the United Kingdom had been declining for a long period before the war broke out, owing to the impoverishment or exhaustion of deposits, the increased costs of extraction and the fall in the value of the metals due to production on a large scale and at lower costs elsewhere; and the war accelerated this decline in production. Though home production at its highest could only supply a fraction of the war demand for the non-ferrous metals, the desirability of maintaining and, where possible, increasing home supplies in order to economise tonnage and exchange led the Ministry of Munitions to set up in March 1917 a Mineral Resources Development Department, the Controller being Sir Lionel Phillips.[7] The department was faced with a very serious position. War conditions had seriously affected a declining industry, which was already hampered by out-of-date methods,[8] small scale production and extensive water logging. The operation of the excess profits duty discouraged the mine owners from increasing their output, in spite of the high prices ruling for minerals (though the price of ores had

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[1] See Vol. VII, Part II, Chaps. II, VI.
[2] Vol. VII, Part II, Chap. II.
[3] Vol. VII, Part III, Chap. X.
[4] Vol. XI, Part III, Chap. III.
[5] Vol. VII, Part III, Chap. X.
[6] *Report of the Controller of the Department for the Development of Mineral Resources in the United Kingdom.* (Cd. 9184 of 1918); HIST. REC./R/1800/4, 36, 38, 45, 46, 49, 50.
[7] He was succeeded in June 1918 by Captain L. M. Cockerell.
[8] C.R. 4408.

not risen proportionately with the rise in the price of the metals), as it involved the exhaustion of their ore reserves with very restricted benefit to themselves. Enterprise was also checked by the fact that it was very difficult to obtain machinery and mining stores, while there was a great shortage of labour, a large number of miners having enlisted and others having migrated to iron and coal mining, where much higher wages were obtainable. The labour difficulty in fact was insuperable. With all its efforts, the only help the department could give was the drafting of 100 German prisoners into the mines, while the leakage to coal and iron mining continued. The labour that remained was criticised by the department as being badly organised, inefficient, and, in spite of comparatively low wages, extravagant. The system of dual employment operating in Cornwall under which the miners gave part of their time to farm work was condemned as "utterly pernicious," though, as it had existed from time immemorial, it was not likely to be abandoned when the industry was clearly declining. The industry also suffered from special burdens—a complicated system of royalties and wayleaves, and heavy costs of rail transport—while, by the existing method of treating tin and wolfram ores, much too high a percentage of the metals was lost.

The department realised that many of the mines which were still being worked at a profit would be unworkable when the war was over, and from the outset it adopted the policy of giving financial help only to such properties as were giving an immediate output, where the advance of money for improved machinery, or for drainage operations would produce an early increase in the amount of ore raised, and where the future prospects of the mines appeared to offer reasonable security for the repayment of the Government loans. Many large schemes for draining waterlogged and abandoned mines were rejected as being highly speculative schemes and not likely to result in increased output until after the war was over.

In four cases mineral deposits were acquired by the department and worked for the Government, two of which, the pyrites mine in Flint and the coprolites (phosphate of lime) deposits in Cambridgeshire, were later controlled by the Explosives Supply Department. The output for war purposes was of great value, but the post-war prospects, owing to the competition of Spanish pyrites and South African phosphate rock, were very dubious. A third property, the Wheal Vincent wolfram and tin mine in Cornwall, was taken over by the department, under the Defence of the Realm Act, in June 1917, as the owners were neglecting its development. The results of working were disappointing, and it was recommended that the mine should be closed down when the war ceased. The fourth venture was exploratory work by means of deep boring in the Lough Neagh district, in Ireland, which was undertaken, at the request of the Ministry of Reconstruction to determine the existence of coal measures, at an estimated cost of £15,000, arrangements being made to reimburse the Government by royalties on any coal discovered.

In addition to these ventures the department arranged for advances by way of loans at 6 per cent. secured by a mortgage on the properties

to some sixteen companies producing tin, lead, zinc and wolfram. The total of these loans amounted to £112,030, the largest advance authorised (£45,000) being in connection with a considerable scheme for draining lead and zinc mines in the Halkyn district near Chester,[1] which was designed to increase the output of ore from 2,716 tons to 12,000 tons per annum.[2]

Besides giving financial help the department helped the mining companies by securing higher priorities for deliveries of machinery, and by giving expert assistance and advice to mine owners, 160 detailed reports being prepared by the department's mining engineers. In addition to its work on metals the department undertook some test boring operations in shale beds in Norfolk and Dorset, but results were not encouraging owing to the high sulphur content of the oil.

On the whole the results of the department's exertions were disappointing. Its highest claim was to have retarded the decline in output, and to have secured for the Ministry some additional output of non-ferrous ores at a time when every ton that could be produced was of great value. The department was never optimistic about the prospects of reviving a moribund industry and the caution with which it avoided speculative and post-war schemes resulted in the concentration of available labour and effort upon schemes from which an immediate increase of output was forthcoming.

The position is summarised in the following table:—

OUTPUT OF ORES IN MINES AND QUARRIES OF THE UNITED KINGDOM, 1913–18.*

(*Figures in tons.*)

	Tin.		Lead.		Zinc.		Wolfram.	
	Mines.	Quarries.	Mines.	Quarries.	Mines.	Quarries.	Mines.	Quarries.
1913..	6,949	1,406	24,265	17	17,294	—	182	—
1914..	6,635	1,450	25,988	25	15,419	—	205	—
1915..	6,427	1,717	20,698	48	12,057	—	327	4
1916..	6,161	1,731	17,084	23	8,476	—	388	6
1917..	5,262	1,314	15,312	10	7,484	—	237	4
1918..	5,376	1,002	14,765	19	8,860	165	295	7

*Based on *Reports on Mines and Quarries, by Chief Inspector of Mines.* Part I. *Divisional Statistics and Reports.*

In addition to its other activities the department drew up a report on the state of the mining industry which was presented to Parliament.[3] Reviewing the post-war prospects of the industry the department urged that the Mines Department should be expanded and strengthened and that there should be some systematic control of royalties and way-leaves, that a more liberal allowance should be made by the Inland

[1] In three other cases help was given by securing a partial remission of excess profits duty with the hope of obtaining an increased output.

[2] For details of these schemes, see Sec/Gen/1547.

[3] Cd. 9184 of 1918.

Revenue Department for depreciation of mining machinery, and that inland rates for the transport of minerals be revised to compete with cost of transport from abroad by sea. The labour difficulty could only be met by a standardisation of wages throughout the mining industry including coal and iron mining, It appeared improbable that any of the non-ferrous metals could be worked profitably in the United Kingdom, unless much better methods of operating were introduced or unless they were protected against foreign competition, but the prospects of working chromite deposits, silica sands (previously imported from France), and barytes (for which we were formerly dependent upon Germany), appeared very favourable.

The broader question of co-ordinating information as to, and methods of dealing with, mineral resources throughout the Empire was not neglected, and following upon a recommendation of the Imperial War Conference (23 April 1917) a committee (under the chairmanship of Sir James Stevenson) was set up by the Minister of Munitions to consider the establishment in London of an Imperial Mineral Resources Bureau.[1]

III. The Economic Character of these Developments.

In reviewing these industrial developments, it is important to make a clear distinction between war and post-war values. A few of them, like the development of the iron and steel industry, could be justified from both points of view, but the bulk of them were frankly war schemes doomed to failure when Government support was withdrawn and foreign competition revived. As war schemes they were abundantly successful; every ton of material that could be obtained represented a direct contribution to the prosecution of the war, and indirectly economised financial resources by reducing purchases which burdened the exchanges. Occasionally the financial cost of the new material thus produced was very high, rising above the cost at which it could be bought in foreign markets, but even in these cases the venture was usually justified by the fact that it economised tonnage at a vital period of the war. The spelter refining industry in the United Kingdom is an illustration of this. When the Ministry decided to give financial help for the development of this industry, prices of spelter in the United States were very high and the cost of the Australian raw material was low. Before the end of the war these conditions were reversed. Prices in America had fallen; tonnage difficulties prevented the shipment of the Australian material; and the refining industry had to depend on Mediterranean calamines of which the price was advancing. Thus every ton of zinc was being produced at a loss, but instead of allowing the industry to close down the Ministry enabled it to continue by subsidising it to meet the increased cost of calamines. This case illustrates the complex nature of the factors which have to be considered when estimating the value of these new industries. Financially, the new venture was unsound, owing to the failure to ship Australian concentrates and to the low prices ruling in the United States; from the tonnage point of view it could not be justified owing

[1] For the report of the committee, 30 July, 1917, see Hist. Rec./R/1800/49.

to the fact that importing calamines from the Mediterranean absorbed as much tonnage as bringing spelter from America, yet its existence was prolonged by subsidy on the ground that American prices were abnormally low owing to over-production and would rise when the United States demand for munitions became effective. It was argued further that the difficulties of the industry were due to the action of the Government in cancelling Australian sailings, and that it deserved support as a valuable post-war industry.[1]

Very few cases can be found of a venture which was a failure from the war standpoint. The most important instance, perhaps, was the effort to increase the output of hematite ore. Actually, after all the efforts of the Ministry, the amount of ore produced from the Cumberland mines declined every year, in spite of much expenditure of money and effort on mining camps and housing schemes. Even in this case it could be argued that the efforts of the Ministry retarded the decline of ouptut due to the enlistment of the miners, and economised tonnage required for importing ore from Spain. The effort to check the decline of non-ferrous ore mining was also, as has been seen above, not very successful and the department recognised that it would have been more economical if every man employed in non-ferrous mines could have been transferred to iron ore mining, owing to the much greater output obtainable per man employed. The practical difficulty of shifting labour of a very conservative type, however, prevented this drastic expedient being seriously considered, though there was a steady migration from non-ferrous to coal and iron mining owing to the higher wages obtainable.

Arguments derived from the post-war utility of an industry had comparatively little weight with the Ministry until the end of the war was in sight. The traders engaged in the industry naturally laid great stress on the post-war importance of developments for which they were seeking the financial support of the State, and their arguments were occasionally reinforced by the advocacy of the Board of Trade. But, with some important exceptions, the Ministry was uninfluenced by these arguments. One of the exceptions was the steel trade, in connection with which there is evidence that the Ministry, in 1917, deliberately undertook to finance extensions which were not expected to produce steel until 1919 or 1920 at the earliest. These extensions aimed at doubling the country's pre-war capacity for steel production and at leaving the industry better equipped to face American and German competition after the war. Similar arguments influenced the Ministry, as has already been seen, with regard to spelter refining and glass manufacture. But in nearly every case in which the Ministry allowed post-war aims to influence its policy, comparative failure followed. Large programmes designed, in part at all events, to meet post-war conditions, diverted steel, man power, building materials, etc. from immediate production, and the more ambitious the scheme the more complete its failure to produce an immediate increase of output.

[1] Similar arguments secured the continuance of a supply of ore to the antimony smelting trade, in spite of the tonnage shortage. (Conference with Board of Trade, 1 August 1918, CRV/Gen/2353.)

Some of the largest steel and iron works extensions are a good illustration of this. In the crisis of the war, they absorbed men and materials which might have been employed on more immediately productive work, while even if their completion could have been achieved within the war period, shortage of iron ore and of coal would have prevented them being worked to anything like their full capacity.[1]

Further illustrations of this point may be drawn from the glass industry, where the obsolete character of the plant, the lack of machinery and hostility to modern methods rendered a large part of the industry unfit to face foreign competition, or the jute industry which could not compete with Indian production by cheap native labour. The excess profits duty operated very harshly with regard to these new industries, as they had no substantial pre-war standard of profit and the duty prevented them from building up a reserve to meet post-war difficulties.[2]

Some of the industries upon which the Ministry spent the most pains, therefore, were doomed to failure as soon as Government support was withdrawn and foreign competition again became effective. This, of course, was only to be expected since the unfavourable conditions which had prevented capital being invested in these industries before the war again became operative as soon as they lost the artificial support of Government subsidies and the quasi-monopoly created by restrictions on importation. These unfavourable prospects led to an agitation in favour of the protection of certain industries described as essential or "key" industries for a term of years, the argument being that these industries were essential for munitions production, that the country had been badly handicapped during the first years of the war by the lack of them, and that some sacrifice of Free Trade doctrine was essential to secure their continuance.[3] The Safeguarding of Industries Act met the situation by imposing an import duty of one third *ad valorem* on foreign manufactures which competed with these new industries. The duty was only to operate for a limited period, and it was anticipated that at the end of that period any new industry which had a commercial future in Great Britain would be strong enough to stand on its own feet.[4]

The Non-Ferrous Metals Act, passed in 1918, had a similar object in view, as it was designed to secure the country against the difficulties that had been created by German control of the non-ferrous metal trades before the war. The Bill made it necessary for all persons engaged in dealing in, trading in, or producing the chief non-ferrous metals to obtain a licence from the Board of Trade. The Bill was hotly opposed. It was resisted, not only as an attempt to prolong bureaucratic control, but as designed to continue an economic war in peace time, to eliminate competition and promote the formation of a British metal ring or group which might exploit the consumer.

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[1] For a further discussion of this, see Vol. VII, Part II, Chap. III.

[2] Sec/Gen/868.

[3] See *Report of the Committee on Commercial and Industrial Policy after the War.* (Cd. 9035 of 1918).

[4] See below, Chap. V.

On the other hand, it was argued that the Paris Economic Conference of July 1916 had imposed on the Allies the duty of making themselves independent of their then enemies for essential commodities, that the extent of the control over world metal markets, and the smelting and refining industries exercised by the German *Metallgesellschaft* before the war had placed the Allies in a very dangerous position. It was argued even by some convinced Free Traders that a period of protection after the war ended was essential in order to secure the industries established during the war against the competition of the highly developed German industries. The Bill was defended as a step to secure economic freedom from the German monopolists,[1] and as a means for securing a supply of materials essential for the defence of the country, and after prolonged debates, it was passed.

[1] One member asked whether the people who resented being rationed with materials in war time by the British Government would prefer being rationed in peace time by a German syndicate.

CHAPTER IV.

CONTROL OF DISTRIBUTION THROUGH THE PRIORITY AND ALLOCATION SYSTEMS.

I. Introduction.

One part of the problem the Ministry had to face—securing and increasing supplies of materials—has already been dealt with ;[1] the second part—the distribution of munitions materials to the best national advantage—was even more complicated. It was approached from two angles, by the administration of priority regulations, and by the practice of allocating supplies of material to special uses. Both methods were designed to make the best use of national resources for munitions production, the emphasis in the former method being upon man power and machinery and in the latter upon materials. The former will be considered first.

The principle of priority administration was a division into direct war work, indirect war work, other necessary work and non-essential work, and this division generally governed the allocation of labour, material and machinery. This elementary classification was, of course, soon elaborated, war work being sorted into the various grades of urgency, shading off into work which though not war work was "necessary for the effective prosecution of the war." But this classification could not be applied universally. Certain exceptions had to be allowed. Thus, financial or diplomatic considerations sometimes made it desirable to maintain a branch of the export trade which depended to some extent on the use of munitions materials. Again, even when enough material could not be released to make the export trade important from the financial point of view, post-war considerations, and the importance of not allowing British markets to be entirely captured by neutral traders dictated the policy of allowing enough material to keep the trade alive. With this object in view the Priority Advisory Committee, later the Industries Committee, was formed.[2]

Moreover, the classification of work as non-essential, and therefore to be curtailed, was not nearly as easy as appeared on the surface. The manufacture of silk, for instance, appeared to be a luxury trade which ought to be suppressed, but the Explosives Supply Department and the Gun Ammunition Filling Department were deeply interested in the supply of silk waste. But the difficulty of dividing trades into broad groups according to their value for war purposes was as nothing compared with the difficulty of assigning priority between the undertakings that ranked as urgent war work. There was not enough

[1] See Chap. II and III.
[2] For details of organisation, see Appendix IV.

labour and material to carry them all out, and the priority authorities had to perform the difficult task of selecting the most vital among many urgently necessary schemes, and here the work was complicated by interdepartmental rivalry. The Priority Department of the Ministry of Munitions came first into the field, and as the Priority Committee attached to it represented other War Departments, its rulings were accepted, in the majority of cases, by them. But, later on, when the shortage of materials became serious its rulings were constantly questioned; the other War Departments began to set up their own priority organisations and the first six months of 1917 were marked by serious interdepartmental conflicts over priority.

Administrative machinery was gradually evolved to meet this difficulty. The position was greatly improved by the establishment of the War Priorities Committee of the Cabinet, and a month before the end of the war, the formation of the Joint Priority Board promised a solution that might perhaps have been reached much earlier.[1]

II. Priority Administration.

The machinery employed by the Ministry was a system of certificates and permits entitling the work so graded to a call upon the means of production according to the grade of priority given. Already, in March and April 1915, the War Office had been instructing contractors to give precedence to Government orders,[2] and the system was rapidly developed by the Ministry, a special Priority Branch being set up under Mr. (later Sir Edgar) Jones in August 1915.

At the beginning, the chief work of the Priority Branch was to consider the relative urgency of the schemes requiring labour, machinery and materials put forward by the various supply departments of the Ministry. Each of them supported the claims of its own contractors and where possible the Priority Branch acted on their recommendations. But when the material or machinery required would not suffice to meet the demands of all the departments in full, the question was remitted to a Priority Committee consisting of representatives of the departments concerned, and, failing a unanimous decision, referred to the Director-General of Munitions Supply. Though the committee had no executive powers and unanimity was required it worked with great rapidity, 200,000 unanimous decisions being come to within the first two years. This committee had no paper constitution, and for a long time was not recognised in official correspondence, but its sphere of action was gradually extended by securing the attendance of representatives of other Government Departments,—the Admiralty, the Contracts Department of the War Office, the Commercial Department of the Board of Trade, the Railway Executive Committee, the India Office, the Post Office, the Stationery Office and the Office of Works—and by the goodwill of these Departments rather than by any legal arrangement, the activities of the Priority Committee covered a large proportion of Government work.[3]

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[1] See Appendix IV.
[2] 94/Gen. Nos./92.
[3] CRV/Gen/0367.

In June 1916 the Priority Branch took over the administration of Circular L.33, previously administered by the Controlled Establishments Branch.[1] Under this circular contractors were bound under penalties to give precedence to war orders, and had in turn the right of issuing a certificate to their sub-contractors placing their contracts in the same class as the original order, class A certificates being given to direct war work, class B to necessary work, and class C to all other work. This classification had to be combined with the grading already adopted by the Priority Branch, the result being a descending scale as follows, class A (P.1, P.2, P.3, and P.4), P.5, B, P.6, C, of which the three highest grades could only be given by the authority of the Priority Department.

Another committee, known as the Priority Advisory Committee, was set up to consider cases of hardship among non-war industries, and keep them alive by distributing a minimum ration of material. Local priority authorities (52 in number) were constituted in the various British Dominions and Possessions which did useful work in reducing the drain upon the resources of the United Kingdom by sifting applications and supporting only those of real urgency. Questions of priority for building and plant extensions were referred to the Munitions Works Board,[2] while the Railway Priority Committee dealt with matters affecting the railways.

Many serious rivalries between Ministry departments were terminated by agreement (*e.g.* the dispute between the Factory Construction Department and the Royal Small Arms Factory at Enfield over machine shafting required by both)[3] by the appointment of a special committee to report on the case, or by conference. Wherever possible general rulings were given. Thus in December 1915 it was decided that tool setters should be allocated first to machine tool manufacture, secondly to rifle work, and thirdly to fuse manufacture.[4]

The work of the branch increased very rapidly. By April 1916, 100 cases a day were being settled, progress being facilitated by the appointment of sub-committees to deal with railway requirements, applications for commercial motors and textile machinery.

A few of the more important problems that were dealt with at this period may be mentioned. The demands of railway companies for machinery and material were investigated and graded on the principle that repairs and maintenance, but no new developments, should be allowed,[5] and applications for extensions to gas works were dealt with according to their importance from the munitions standpoint.[6] The shortage of motor transport presented a difficult priority problem, and the Priority Committee required would-be purchasers of motor lorries and steam wagons to sign an undertaking giving the Ministry the right to take over any vehicle which was not being used for munitions work or for other purposes of national importance.[7]

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[1] See Appendix III ; M.W. 56129/4.
[2] General Procedure Minute No. 69 (23/1/17) ; See below, p. 61.
[3] (Printed) *Weekly Report* No. 30 V. (19/2/16).
[4] *Ibid.*, No. 21 V. (18/12/15).
[5] *Ibid.*, No. 23, V. (1/1/16) ; No. 27, V. (29/1/16).
[6] *Ibid.*, No. 30 V. (19/2/16).
[7] *Ibid.*, No. 28 V. (5/2/16).

The original policy of the Priority Committee with regard to coal-mining machinery was to give priority B for machinery required to maintain continuity of output, but to refuse priority for machinery intended only to increase output save in very exceptional cases. By the middle of 1916 a coal shortage was being envisaged, and the installation of coal-cutting and other labour-saving machinery was being pressed on the Priority Committee by the Director of Materials, and priority B was given to all coal-mining machinery which was likely to lead to a substantial increase in production in the immediate future.[1]

Up to about the middle of 1916 priority regulation within the Ministry worked smoothly enough. But with the growing independence of the supply departments and the increasing shortage of materials, machinery and labour, conflicts over priority became more acute. The working of the priority system was hampered by the fact that there was no clear definition of the respective functions of the Priority Department and the various supply departments, and no machinery—except an appeal to the Minister—to settle disputes between them.

Under certain of the Orders in Council dealing with the control of commodities, the priority certificate was recognised as the sole machinery of control ; under others, the priority certificate was either ignored altogether, or by its side was set up a system of licensing, the effect of which was to make the priority certificate not the instrument of effective control, but merely " a more or less useful weapon in the hands of an applicant desiring to obtain a licence from the authority who in actual practice exercised the control."[2] Again, allocations of material by supply departments frequently conflicted with priority rulings, for, while the duty of providing supplies of any given war material was definitely assigned to a self-contained department of the Ministry (the Priority Department) acting without interference from other departments, the duty of distributing these supplies often fell in practice to various sections of the steel, explosives or raw materials departments, who frequently acted without reference to each other or to the Priority Department.

Thus, though a priority certificate was legally and technically required for the use of most of the controlled materials, the practical control of certain of them rested with other sections of the Ministry or with other Departments. Licences for the use of cast iron pipes, for instance, had to be obtained from the pig iron section of the Iron and Steel Department, of steel and iron tubes from the tube section of the same department ; permits to manufacture metal working machinery had to be obtained from the Machine Tool Department ; permits to manufacture small tools, steel balls and bearings, cranes and elevators from the Small Tool Department ; permits to manufacture crucible special steels from the Controller of Iron and Steel Production ; while permits for the use of most of the non-ferrous metals were obtained from the Raw Materials Department. The actual, as distinguished from the legal activities of the Priority Department,

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[1] (Printed) *Weekly Report* No. 53, XI. (5/8/16) ; Sub/17771.
[2] Letter from War Trade Department, 16 September 1918 (CRV/Gen/2095).

therefore, were limited to all grades of open hearth and Bessemer steel (including tin and terne plate, wire and wire rope), copper and brass (other than domestic scrap brass), malleable cast iron and wrought iron in quantities exceeding 4 cwts., electrical, telephone and telegraph material, etc.[1] These complications produced serious difficulties and misunderstandings. For instance, the Priority Department was found to be issuing or refusing certificates for the use of cast iron pipes, the control of which was vested in the Iron and Steel Department, for the use of asbestos which was controlled by the Admiralty, and for the use of canvas which was controlled by the War Office, while conversely, though the control of lead was formally vested in the Priority Department, the real control remained with the lead section of the Raw Materials Department.

A list of the materials controlled by the Ministry, therefore, was not equivalent to a schedule of the materials which required reference to the Priority Department. Iron, for instance, was not controlled by an Order under the Defence of the Realm Regulations, but owing to the deficiency of supply, instructions had been issued to the blast furnaces that iron must only be supplied under certain restrictions. It was legal to use iron without a permit, but in practice it could only be obtained for urgent war work. But even if it had been quite clear which classes of material were practically as well as legally controlled by the Priority Department, this would not have swept away all difficulties. A priority permit for the manufacture of bicycles or motor cars covered a wide variety of materials, and this made it almost impossible to draw up any comprehensive list of the articles which required priority certificates or any classification of the materials subject to priority control.

The Minister recognised the difficulty of the position and many attempts were made to define the jurisdiction of the Priority Department and to delimit its sphere in relation to the supply departments.[2] The theoretical solution—the primacy of the Priority Department—was not accepted by all the supply departments, and though the formation of the Munitions Council improved the situation, no complete solution had been found by the end of the war.

These anomalies were not only a source of confusion within the Ministry, but of embarrassment to other Departments, especially to the War Trade Department, which found itself dealing with the Priority Department with regard to certain materials and with sections of Ministry supply departments in other cases. The Ministry suggested that *all* applications for licence to export should be submitted to the Priority Department, but the War Trade Department could not agree to this.[3] It was impossible to refer to the Ministry Priority Department questions as to the desirability of allowing export of articles not controlled by the Ministry. The Priority Department had neither the experience nor the information necessary to enable it to adjudicate

[1] Letters from War Trade Department, 22 April, 30 May 1918 (CRV/Gen/0543, 2095).

[2] CRV/A/212.

[3] Letter to War Trade Department, 15 May 1918 (CRV/Gen/2095).

upon applications for leave to export, which were carefully considered by the War Trade Department and its sub-committees, the decision being based upon blockade, financial, tonnage and semi-political considerations.[1] The suggestion that the Priority Department should be consulted instead of certain of the supply departments of the Ministry was also unpalatable to the War Trade Department. "It would compel us no longer to consult the authority in whom the effective control resides, but merely to accept the views of the Priority Department on subjects upon which their opinion is not regarded as conclusive, even within the Ministry of Munitions itself."[2]

It was quite clear that the whole situation had become confused and difficult to a degree which embarrassed the whole mercantile community as well as the Government Departments chiefly concerned.[3] It could not be cleared up by interdepartmental correspondence, and could only be placed upon a logical and systematic basis by means of a complete re-statement of the principles of priority control, and a clear definition of the functions of the Priority Department in relation to the various Control Orders. At that late stage (May 1918) this was found to be impracticable, as it would have created as much confusion as it cured, but by arrangement between the Ministry and the War Trade Department a *modus vivendi* was adopted,[4] which defined and recognised the existing practice as between the two Departments, viz: that the War Trade Department should continue to refer applications for leave to export certain materials direct to the supply departments of the Ministry, while the Priority Department was to be consulted as to all grades of open hearth and Bessemer steel and the remainder of the commodities detailed above.[5]

The monthly reports on the relative urgency of various munitions which began from March 1916 were a valuable guide in assigning priority. The stores were grouped in three classes A, B and C (later 1, 2 and 3, items of special importance in Group 1 being starred). From February 1917 the report was extended and made more valuable by the addition of lists from the War Office, Air Board and India Office, an Admiralty list being added in March, while some closer indication of the relative urgency of the Ministry demands falling in Group 1 was given by a preliminary grading. The Ministry grading of its Group 1 demands in the list of 14 March 1917 may be quoted by way of illustration:—

(1) Aero-engines, aeroplanes and seaplanes.
(2) Guns.
(3) Tanks.
(4) Railway material.
(5) Motor vehicles.
(6) Steel.
(7) New propellant factory.
(8) Phosphorus and other chemicals.

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[1] Letter from War Trade Department, 30 May 1918 (CRV/Gen/2095.)
[2] *Ibid.*, 16 September 1918.
[3] For illustrations of the embarrassment to traders, see CRV/Gen/2095.
[4] 15 July 1918 (*Ibid.*). [5] See above, p. 48.

As a result of the progress in laying down general priority principles, and of the accumulation of experience in interpreting them, these monthly statements of the relative urgency of various munitions became more valuable as time went on. By June 1917 a reversion had been made to the A, B, C classification ; a fourth group D in which supply was satisfactory being added in November 1917. Group A was later (August 1918) subdivided into four classes, on lines laid down by the supply departments concerned, while relative priority in A.1 (for which there was the most competition) followed decisions made by the Co-ordinating Committee of the Council,[1] or by the Minister, and varied from time to time with variations of supply and demand. Thus, in the August 1918 list of the Ministry of Munitions the manufacture of mustard gas and other gases was given the first place, followed by the new type of 18 pdr. equipment, tanks, mechanical tractors, aeroplanes and seaplanes, certain types of guns, the maintenance of mechanical transport vehicles, and of railway material, plant for synthetic ammonia and synthetic nitric acid, the supply of mechanical transport materials and of railway material, agricultural machinery, steel, tars and oils. By the end of October gas warfare still came first, but agricultural machinery, guns, steel, tars and oil had fallen out of the specially urgent list, while spare parts for mechanical transport had been moved up by the Minister at the request of the War Office, in view of the demand resulting from the advance in the Balkans,[2] and optical munitions had also been given higher priority.

From time to time owing to the special urgency of the demand, special priority was given to certain undertakings. Thus in the early part of 1916, decisions of the Priority Committee facilitated the erection of benzol plant and of small arms factories.[3] Later in the year special priority was given to explosives factories and the manufacture of a new type of gas mask.[4] At various dates in 1917, aircraft, tanks, locomotives and agricultural machinery obtained special priority[5] and in February 1918 a special super-priority was given to tanks by the Minister's order.[6] The interpretation of this order led to some controversy, as the Priority Department was reluctant to accept the inference that all plant for tank manufacture—even ventilating plant which was not an absolute necessity—should automatically obtain a P. 1. certificate thereby jeopardising urgent work on aircraft, etc. and by agreement with the supply department the Priority Department was allowed to exercise its discretion. The super-priority was retained until July 1918 when the manufacture of mustard gas was given the first place (without any super-priority) until September, when the Minister decided it was to be given special priority " no matter how many general rules of the Ministry had to be broken."[7]

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[1] Special committees were occasionally appointed to investigate priority questions, *e.g.*, the improvement of the priority for petrol locomotives which were urgently needed at the Front. March 1918 (M.C. 585).

[2] D.M.R.S. 460A.

[3] (Printed) *Weekly Report* No. 12 V (16/10/15).

[4] *Ibid.* No. 53, XI (5/8/16).

[5] HIST. REC./R/1000/108 ; D.M.R.S. 430 B.

[6] M.C. 1025, 2121.

[7] *Ibid.*

III. Allocations of Munitions Material.

As has been seen above, side by side with the growth of priority machinery, another form of control based upon the distribution of munitions materials through the supply departments had grown up. Certain departments—the Raw Materials Department and the Explosives Supply Department—achieved practical independence of the Priority Department; but after a considerable struggle the Priority Department succeeded in maintaining its authority with regard to steel distribution. At the beginning the Ministry lacked the statistical equipment and data required for such allocation, as the Department had no means of estimating total current resources against total current requirements. But as these data were accumulated the allocation method became more and more important. Considerable progress was made in the summer of 1916 in controlling the distribution of the whole output of steel, and priority among Ministry consumers was assigned by the Priority Department with the help in special questions, like the allocation of constructional steel, of the Munitions Works Board.

The system by which a section of one Government Department settled priority questions for other Departments was already breaking down, and the Admiralty and War Office had started priority departments of their own, issuing rival permits. The allocation of steel in particular brought the Priority Department into conflict with the Admiralty. The Admiralty accepted the principle that the actual machinery of issuing licences for steel should be operated by the Ministry (which was by far the largest user of steel), but resisted the assumption that the final decision as to the distribution of steel lay with the Priority Committee, even though it was represented on that committee. The course of the struggle does not concern us here, for though its issue was in doubt until the last twelve months of the war, the Admiralty gradually receded from its original contention that Admiralty demands must be "honoured without question," and that the directions of Admiralty overseers must be obeyed by steel manufacturers in preference to the orders of the Iron and Steel Production Department of the Ministry.[1] The Ministry held firm to the principle that the issue of permits and licences must be limited to the Department which exercised control, and could only undertake to honour Admiralty certificates when supplies were sufficient. But in the last year of the war when steel distribution became a vital national problem, the direction of the War Priorities Committee of the Cabinet was taken on large questions of allocation or compulsory reductions of allocation, minor questions being settled by subsidiary bodies like the Works Construction Sub-Committee of the Cabinet, the Steel Allocation Committee and the Munitions Works Board. Tension was relieved by the preparation of steel budgets allocating the total production or importation of the country among the various Departments, after conferences between them. Finally, a constitutional means of harmonising competing demands was provided by the formation of the Joint Priorities Board.

[1] CRV/Gen/1404.

The steel budgets allocated a certain tonnage from the estimated production of the year for each Department's requirements. The allocation was a provisional one, and liable to variation with large scale changes in the relative urgency of war demands, but as a general rule it was expected that each Department should find all the steel it required for extensions and so on out of this allocation. This relieved the Priority Department of the necessity of attempting to settle which was the most urgent of the demands put forward. But when a Department advocated an extension for which it was not prepared to provide the steel, difficulties arose which could only be settled by the Cabinet.[1]

The Allocation of Urgent Supplies Board, which included representatives of the Ministry supply departments, of the Priority Department and of the War Office and Admiralty, did useful work in distributing supplies of steel castings, ball bearings, steel tubes, crank axles so as to adjust as far as possible conflicting claims, as well as in allocating existing capacity for the manufacture of these supplies and of tanks, aero-engines, locomotives, motor transport and certain Admiralty requirements, and for the provision of spare parts.[2]

These steel budgets depended on the maintenance of ore imports, and like all other allocations of material were dominated by the tonnage situation during the last two years of the war. Originally demands for munitions shipping were put before the Director of Transports at the Admiralty; later on, they came before the Shipping Controller; and still later, when the shortage of shipping became serious, the demands were put before an interdepartmental Tonnage Priority Committee under the chairmanship of Sir L. Chiozza Money, which having full knowledge of the amount of shipping available for all purposes, allocated tonnage to the various Departments.

The Ministry of Munitions found that the tonnage available for it fell far short of the amount it required, and in order to make the best use of it, set up a Shipping Priority Committee (June 1917) to assign priority for shipment in order of urgency, the details being worked out by the Department of Munitions Overseas Transport.[3] This department drew up quarterly estimates of departmental requirements. The percentage in October 1917 was as follows:—

Department of Iron and Steel Production	59	per cent.
,, ,, Explosives Supply ..	$18\frac{1}{2}$	,, ,,
,, ,, Shell Manufacture ..	$7\frac{1}{2}$	,, ,,
,, ,, Non-Ferrous Metals ..	$9\frac{1}{2}$	,, ,,
Other Departments	$5\frac{1}{2}$	,, ,,
Total ..	100	

[1] *e.g.* The Admiralty and the War Office both wished for the construction of a peat briquetting factory in France, but neither was willing to provide the steel for it (M.C. 45).

[2] Proceedings of Allocation of Urgent Supplies Board, June to November, 1917 (HIST REC./R/1000/108).

[3] C.R. 4397.

Very serious difficulties had to be faced. The submarine campaign frightened many neutral ships out of the trade with the United Kingdom, thus further reducing the shipping available, though this difficulty was met to some extent by an insurance bounty which encouraged them to face the increased risks. Competition between food and munitions shipments was acute from May 1917 onwards, and shipping help given to the Allies had to be found from dwindling resources. Owing to submarine losses[1] and the loan of tonnage to France and Italy for the importation of cereals under an agreement of 3 November 1917 a deficit of from 6–8 million tons of British imports was anticipated by the Import Restrictions Committee for 1918, and to fill the gap a severe cutting down of the tonnage demands of the various Departments took place, together with the bringing in of ships from distant seas and concentrating them on shorter voyages, which both multiplied the carrying capacity of ships and enabled the convoy system to be successfully employed. In order to help in the transport of the American Army in the earlier part of the year it was proposed to postpone a proportion of the shipment of munitions and foodstuffs from North America, sacrificing about 50,000 tons a month, which was to be made up later in the year with the aid of American shipping (the American shipbuilding programme being much in arrears). Under the first cut recommended by the Imports Restriction Committee (1 December 1917) Ministry of Munitions imports were reduced by 1,550,000 tons, from 12,500,000 tons imported in 1917 to 11,000,000 tons.[2] When a further cut became necessary owing to the serious position, it was proposed that Ministry imports should be reduced to 10,000,000 tons which could only be effected by reducing the steel available for shell production by 500,000 tons, by reducing the steel allocated to the Admiralty, War Office and Railway Executive, and by reducing the importation of nitrates.[3] As the tonnage demands of the various departments of the Ministry of Munitions amounted to 15,000,000 tons, the strictest allocation of the available tonnage became necessary, and all priority arrangements within the Ministry of Munitions had to be governed by these allocations. The amount of material allotted to the various departments was decided upon by the Munitions Council, and priority regulations had to follow the main outline of these allocations.

Sometimes the interdepartmental allocation had to be upset owing to increased stringency in the supply position. Thus, under the general cut in tonnage enforced by the Restriction of Imports Committee in February 1918 the allocation of steel for railways, as settled at an interdepartmental conference in the previous November, was halved.[4] Later, owing to the high priority given to the tank programme by the Army Council, the Railway Executive were informed that there would

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[1] During 1917 the net losses of British ships amounted to 2,691,000 tons (HIST. REC./R/2060/25).

[2] Food imports were reduced at the same time by 2½ million tons to 13,056,000 tons. (HIST. REC./R/2060/25).

[3] 11 February 1918 (D.M.R.S. 155). The recommendation of the Restriction of Imports Committee was accepted by the War Cabinet on 15 February.

[4] CRV/Gen/1564.

be great difficulty in supplying steel plates and were urged to give up their plans for new locomotives, carriages and wagons.[1] The Executive made an emphatic protest (21 February 1918) pointing out that the haulage capacity of the railways was so depleted that by the end of 1918 the railway companies would be unable to meet the transport requirements of the Government Departments, which would have a serious reflex action on steel production. Mr. Churchill, however, was bound by the War Cabinet decision of 15 February, and was unable to promise more steel than the amount allocated unless some Department failed to take its share, or unless the steel output was raised, or unless the War Cabinet approved the railways being supplied at the expense of some other source. As events turned out, the railways were later able to obtain more steel, owing to an improvement in the transport position, and to the fact that the Admiralty and Shipping Ministry were unable to use all the shipbuilding steel allocated to them owing to the shortage of labour in the shipbuilding yards.

As the competition for tonnage between Government Departments became more acute some very serious questions arose. At the beginning of 1918 the demands of the Ministry of Munitions and the Ministry of Food on the available tonnage roughly balanced, and owing to the shortage of shipping had to be cut down by the Cabinet in accordance with their general war policy. But on many points of detail there was acute controversy. The Ministry of Food had taken over responsibility for the importation of oils, oil-seed, and fats required both for the manufacture of margarine, and for the soap and candle trades in which the glycerine required for munitions purposes was a by-product. The importation of the oil-seeds and fats had to be reduced owing to the loss of shipping at the end of 1917,[2] and the Ministry of Food stated that in the event of a shortage, margarine makers would be supplied in preference to soap and candle makers, thus reducing the output of glycerine by nearly one half. Mr. Churchill brought the question before the Cabinet (January 1918),[3] urging that the supply of material to the soap and candle trades should be maintained at a certain minimum, even at the expense of margarine, that supplies of linseed oil should be diverted from the linoleum trade for the production of glycerine, and that the installation of fat splitting plants in India and Ceylon should be sanctioned, even though the resulting economy in tonnage would not mature until 1919. These proposals were dealt with as follows. On 4 January the War Production Committee decided that no linseed oil should be allowed to linoleum manufacturers and that the stocks held by the trade must be handed over to the Food Controller for glycerine production. The Board of Trade protested that there was no substitute for linseed oil, but as the trade was only employed to the extent of about 25 per cent. on Government orders, the Cabinet decided that it would have to be closed down in the national interest,

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[1] A special sub-committee of the Priority Committee had been established to deal with demands for railway material.

[2] About 70,000 tons had been imported annually, of which about half was used for margarine production.

[3] M.C. 333.

though a few days later (11 January) it decided that existing stocks might be retained, priority being given to Government requirements. The Treasury had sanctioned fat splitting plants in Calcutta, but refused to sanction similar plant in Ceylon, as the operation of any of these plants would be very costly owing to the fact that 90 per cent. of the output was a waste product for which there was no market in the East. Lord Curzon, to whom the question was remitted, urged that the Indian plant should be pushed on and that the Ministry should consider the installation of similar plant in the Argentine to utilise its supplies of linseed and tallow. Fortunately the improvement in the tonnage position made it unnecessary to obtain a Cabinet ruling as to the relative importance of margarine and glycerine, as sufficient material became available to maintain production of the latter.[1]

During the last two years of the war, both the general policy which determined priority within the Ministry, and the preparation of the Ministry's case in competitions for tonnage rested with committees of the Munitions Council. For instance, in November 1917, the Minister appointed a Council Committee to obtain information on the proposed importations of other Government Departments and enable him to draw attention to "unnecessary or extravagant claims which prejudice the supply of munitions to the Armies."[2] The committee, after working on tonnage estimates furnished by the Interdepartmental Tonnage Priority Committee, which showed a deficit of 725,000 tons a month for the first half of 1918, reported (7 December) that the Food Ministry might economise in the importation of oil seeds (by increasing oil extension plants in India and Africa), oil seed cake, margarine, barley and maize, raw fruits, meat, poultry and game ; that the Timber Controller might economise by reducing the importation of pit props from Spain (obtaining them from Norway or at home) ; that the Board of Trade might reduce its importation of paper and paper-making material ; and that the Ministry of Munitions might reduce its importation of Narvik iron ore in view of the large stocks then held. The committee estimated that these economies would save 242,000 tons per month, and reported that the position, which would be eased by the reduction of supplies to Russia, would be further improved by the erection of plant for extruding oil abroad, and by reducing the import of barley for brewing, the responsibility in both cases resting with the Ministry of Shipping.

IV. Interdepartmental Decisions.

But though rivalry was diminished to some extent by tonnage allocations in 1917 and 1918, interdepartmental priority was always a thorny question.

The Priority Committee had done important interdepartmental work from the very beginning. In November 1915 for instance, it was helping the Admiralty to get gauge makers for a torpedo factory, the Military Aeronautical Department to obtain a supply of tubes, and the Post Office to increase its fleet of motor vans.[3] In January

[1] 11 April 1918.
[2] M.C. 333.
[3] (Printed) *Weekly Report* No. 16, V (13/11/15).

1916 it settled a conflict over machinery required both by the gun department and by the War Office, and in February an agreement between the Admiralty and the Board of Trade regulated the priority to be enjoyed by grain elevators and other unloading plant.[1]

Difficult questions were considered at interdepartmental conferences between the Admiralty, War Office, Board of Trade and the Ministry. A conference in March, 1916, came to unanimous conclusions about the distribution of petrol, which was already becoming a difficult question.[2] By April the shortage of lubricating oils was engaging the attention of the Priority Department, the Admiralty, War Office, and Ministry of Munitions being interested. A similar conference considered the demands of the Admiralty, and of the gun, explosives and trench warfare departments on the limited supply of solid drawn tubes,[3] while at a conference with the War Office (June 1916) arrangements were made for releasing boot making machinery for urgent munitions purposes.[4]

Already the conflicting interests of the various Departments were making priority regulation difficult. The aims of the Board of Trade for instance—the maintenance of exports and the capture of German trade—could not easily be reconciled with the necessity of diverting energy to munitions output. Among the first cases to be considered by the Priority Committee were certain contracts for electric lighting, and plant for handling ore in China, and the manufacture of rice milling machinery for the East.[5] The Board of Trade was specially anxious that exports of British machinery should be allowed. In the autumn of 1915 the Priority Committee had adopted the general principle that exports of machinery by firms not fully engaged on munitions work might be allowed to the extent roughly of one-third of a firm's output, if it appeared that the export of such machinery would be of special value to the British Empire or its Allies. But this principle had to be narrowed as time went on.[6] In January 1916 licences for the export of textile machinery had to be curtailed, owing to their effect on delaying orders for munitions machinery,[7] and it was further decided that (with the exception of hosiery machinery and webbing weaving machinery, which was urgently required by the War Office) no more textile machinery was to be made for the home market.[8] The employment of labour on motor cycles and other cycles for export also had to be checked (March 1916).[9] The probability that British makers of electrical machinery would soon have completed all their orders for war purposes made it advisable to consider the authorisation of orders for export (May 1916), but concessions soon led to further demands,[10] and the policy with regard to the export of machinery became more stringent with the growth of the munitions demand for it.[11] The

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[1] (Printed) *Weekly Report*, No. 27, V (29/1/16); No. 30, V (19/2/16).
[2] *Ibid.*, No. 36, V (1/4/16).
[3] *Ibid.*, No. 38, XI (22/4/16).
[4] *Ibid.* No. 46, XI (17/6/16).
[5] *Ibid.*, No. 19, V (4/12/15).
[6] *Ibid.*, No. 11, V (9/10/15).
[7] *Ibid.*, No. 24, V (8/1/16).
[8] *Ibid.*, No. 29, V (12/2/16).
[9] *Ibid.*, No. 35. V (25/3/16).
[10] *Ibid.*, No. 53, XI (5/8/16).
[11] *Ibid.*, No. 45, XI (10/6/16); No. 72, VIII (16/12/16); No. 50 XI (15/7/16).

export of tin plates was another profitable branch of trade that had to give way to munitions demands, and the limited amount which might be exported was settled by the Priority Committee and the War Trade Department in consultation.[1]

Occasionally it was desirable to allow export of materials that could, with difficulty, be spared in order to provide cargo. Thus the export to Australia and New Zealand of galvanised corrugated sheets made of shell discard steel would provide outward cargo for the ships bringing meat and wool thence,[2] but the export of copper tubes for sugar plantations could not be allowed owing to the shortage of copper tubing. There was also some conflict of interest over importations, as when the Priority Committee refused applications for the importation of margarine-making machinery required by the Board of Trade.[3]

In May 1916 it was arranged, by agreement between the Priority Committee and the Board of Trade, that all instructions to commercial firms as to the relative urgency from the national point of view of their commercial orders were to be given by the former after consultation with the latter. The committee was not bound to act upon the Board's recommendation, but the latter was to have the right of appeal from an unfavourable decision.[4]

As has been seen, inter-departmental conflicts over priority became very serious in the last two years of the war, and appeals to the Cabinet, which alone could decide which of two necessary schemes must be sacrificed, multiplied. To meet the situation the War Priorities Committee of the Cabinet was set up in October 1917.[5] The Committee consisted of General Smuts (Chairman), Sir Eric Geddes (Admiralty), Lord Derby (War Office), Mr. Winston Churchill (Ministry of Munitions), Lord Cowdray (Air Board), and Sir Auckland Geddes (National Service), and dealt with questions of policy and principle, questions of detail being referred to a permanent sub-committee.

Sub-committees were appointed to deal with special problems. Priority for machine tools became unusually important in the autumn of 1917, since America's preparations for munitions manufacture threatened to limit the supply from America. The Admiralty, which required large amounts of new machinery for producing guns for merchant ships, and for standard shipbuilding, was working through the Machine Tool Department harmoniously, but demand was outrunning supply, and a standing Machine Tool Priority Committee was set up (30 September, 1917) to advise the Machine Tool Department on priority questions.[6] Similarly an Electrical Allocation Committee of the War Priorities Committee, later known as the Electrical Services Sub-Committee, was set up to assign priority as between the applications of various Departments for generating plant, and to secure uniformity and economy in

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[1] (Printed) *Weekly Report*, No. 58, XI (9/9/16).
[2] *Ibid.*, No. 72, VIII (16/12/16).
[3] *Ibid.*, No. 31, V (26/2/16).
[4] *Ibid.*, No. 43, XI (27/5/16).
[5] M.C./521.
[6] The Committee consisted of Sir James Stevenson, Sir Glynn West, Sir Arthur Duckham, and Sir Alfred Herbert. (M.C. 136).

the use and supply of electrical energy throughout the country. Electrical energy was to be bought rather than made, and alternating rather than direct current used whenever suitable.[1] A few special cases may be mentioned to illustrate the general character of the work done by the War Priorities Committee. When the Admiralty resisted a demand by the Aircraft Board for an over-riding priority for steel, which would have entitled them to their full quota of steel every week, however much production fell off, the question was referred to the Steel Allocation Committee which decided (November 1917) that no such over-riding priority should be given.[2] Again the demands of the Food Ministry for additional tonnage for the importation of phosphate rock were investigated, while in January 1918 owing to the very serious food situation, special priority was given to the shipment of cereals from North America for the next three months even though it involved the postponement of munitions shipments.

Time was an important factor and plans for war purposes which could not be completed within a reasonable period had to give way to urgent war demands. Thus in November 1917 the Cabinet decided that the Admiralty must curtail its demand for steel for airship sheds as these were not to be completed until 1919 or 1920, and the same kind of steel was in urgent demand for immediate war work.[3]

Many difficulties arose over the priority to be enjoyed by industries which both developed home resources and had a special post-war importance. The dye industry may be quoted by way of illustration.[4] Recognising the dangerous dependence of the country on German dye-stuffs, and the fact that in 1914 all except ten per cent. of the dyes upon which the great textile industry depended had come from Germany, the Board of Trade had made special efforts to foster the industry. The Government had given financial assistance to a new company, British Dyes Ltd., but the effort to develop a sufficient industry to make the country self-supporting had been hampered by the fact that the Ministry of Munitions had found it necessary to divert the chief energies of the company to the production of materials for explosives. Dyes for current needs were obtained by extensions to private firms, and from Swiss manufacturers who returned finished dye-stuffs in exchange for raw materials, but the Board of Trade did not lose sight of its ultimate object, which was to create an industry which would be capable of supplying a full range of dye-stuffs after the war, and rendering the textile industry independent of German dyes. The industry was treated as a munitions industry and allowed P.4. priority until August 1917, when in view of the steel shortage the Priority Committee decided that this priority could not be allowed to extensions which would only become of great importance on the termination of the war. Thus the interests of the Ministry of Munitions and the Board of Trade clashed. Conferences followed, and the War Cabinet,

[1] C.R.V./Gen/2340.
[2] A.S. 23598/1917.
[3] In the summer of 1918 the Minister of Munitions protested against the absorption of building labour in aerodrome construction. (M.W.L.R. 15207/62).
[4] M.C. 167.

influenced possibly by the contention than an efficient dye industry in Great Britain would deprive Germany of a useful diplomatic counter at the Peace Conference, decided (9 October) that the dye industry was to be treated as a war industry for all purposes. This settled the question for the time, and dye works extensions were pressed on, a large scheme being approved by the War Priorities Committee of the Cabinet in February 1918. The demand for constructional labour for this scheme, however, was so great that in July 1918 the Works Construction Sub-Committee referred it to its parent body for reconsideration, as the execution of post-war schemes of this kind prejudiced urgent war work. The Cabinet, however, maintained its decision (5 July).

A similar principle decided the priority to be allowed for the Billingham factory for producing nitric acid by fixing atmospheric nitrogen, at an estimated cost of £400,000 and employing 2,000 men on constructional work for more than two years. In this case the Ministry of Munitions supported the scheme in view of the fact that it would eliminate dependence upon Chilian nitrates to the extent of 12½ per cent., save tonnage on a long voyage, and be of permanent post-war value for agricultural purposes, but the Treasury demurred. The difficulty had to be solved by the War Priorities Committee of the Cabinet, which sanctioned the scheme in February 1918 and maintained its decision (5 July 1918) after an appeal from the Works Construction Sub-Committee, which doubted the wisdom of allowing priority to a scheme which absorbed so much constructional labour, and which could not mature for a long time.

These cases, and those of certain steel works extensions which are considered elsewhere,[1] illustrate the difficulty of deciding questions of principle over which the War and Civil Departments of State and the immediate or permanent interests they represented came into conflict. On the whole the long view triumphed, and even at the crisis of the war, men and material were being employed on works, which though of great future value, detracted from, rather that added to, the strength of the country in the struggle in which she was then engaged.

Occasionally the War Priorities Committee gave a general priority ruling, as in September 1917 when it decided that the reduced airship programme and the aeroplane programme should have priority after shipbuilding, even if it involved a reduction in the output of other munitions such as shells and rails.[2] When giving general directions of this kind the War Priorities Committee tried to follow general principles, distinguishing between productions in equally urgent demand by considering the amount of labour and material they would absorb. In an interim report (31 January 1918) the Information Sub-Committee, though not in a position to show the cost of labour and steel of many war requirements (falling back on money value as a rough index of the cost in both labour and material) was able to give an interesting comparison of relative cost in steel and labour of certain

[1] See Vol. VII, Part II, Chap. III.
[2] This decision was confirmed by the Cabinet on 14 November.

important stores.[1] The following table shows the number of these stores which could be produced with the same amount of (*a*) man-power, (*b*) steel required to produce one class A standard ship of 8,000 tons deadweight carrying capacity :—

Store.	*Man Power.*	*Steel.*
Torpedo boat destroyers	·66 ..	4·7
Submarines	1·1 ..	13·7
15-in. guns	4·4 ..	7·8
15-in guns and mountings	1·9 ..	2·2
15-in. shells	1,870 ..	2,218
18-pdr. field guns	77·7 ..	1,518
Lewis machine guns	2,720 ..	21,120
Rifles	17,949 ..	304,615
21-in. torpedoes	97 ..	1,414

Thus it appeared that standard ship construction was relatively economical of labour but not of steel. The value of information of this kind in assigning priority among various munitions programmes was evident.

The Information Sub-Committee also produced figures showing the value of the stores and stocks of material owned and produced by the Admiralty, War Office, Ministry of Munitions, and the annual demands of the India Office, Post Office and Railway Executive Committee, together with an estimate of the reserves authorised and actually held by various Departments. There was evidence that the reserve stocks were too high, since manufacturing capacity was far in excess of the supply of labour and material, and the Departments were urged to bring these reserves into consumption.[2]

In its anxiety to control the formation of excessive reserve stocks the War Priorities Committee suggested that the standard reserve should not exceed three months' consumption. The Ministry of Munitions had little difficulty in showing that many other factors had to be taken into account, dependence upon foreign sources, the length of the voyage and the tonnage facilities available, the necessity of maintaining a considerable reserve in order to avoid fluctuations in price, the risk of loss by explosion or fire, the extent to which reserve stocks of substitutes were available, the necessity of insurance against the failure of new designs, the position of the Allies with regard to supplies of a particular store, and the changing nature of the campaign. All these factors affected different stores in varying degrees, and though in a few cases too large reserves had been accumulated owing to the failure of supply departments to realise the real stringency of materials, many of the items to which the War Priorities Committee drew attention could be explained by the necessity of considering other factors besides the rate of consumption. Thus the heavy stocks of magnesite, due to advantageous buying when prices and freights were relatively low, had saved the country large sums of money and removed the danger of depending for an essential material upon an increasingly dangerous sea voyage ; the large accumulations of trench warfare material were

[1] C.R. 4404.
[2] 27 February, 1918 (C.R.V./Gen/0487).

due to the transport difficulties in the 1917 campaign; the heavy stocks of propellant were accumulated in order to minimise the danger of dependence on the United States, and so on.

The possession of information of this kind enabled the War Priorities Committee to formulate decisions on broad grounds, which marked a great advance on the old system or lack of system under which priority was the battle-ground of conflicting Departments, victory going to the strongest, irrespective of the merits of the case. At the same time the closer personal touch between the officials of the Ministry, Admiralty and War Office brought about by means of the Allocation Committees had gone a long way towards removing friction.

The final step was the fixing of the relative priority between the various items in the A.1 lists of the Admiralty, War Office and the Ministry of Munitions, and after elaborate interdepartmental negotiations, a Joint Priority Board consisting of the heads of the priority branches of these three Departments was appointed.[1] The Board was to ensure the execution of the decisions of the War Priorities Committee, to limit the competition between Departments, and unify the form of the priority certificates used by them. Another of its functions was to grade orders in a schedule compiled by the Board under the direction of the War Priorities Committee, and the Board was to be responsible for the periodical revision of this schedule. Any order or contract not graded in this schedule came automatically within Class A/P.4 priority, and was not to be given higher priority except with the consent of the Joint Priority Board. This machinery, however, was only just getting into working order at the time of the Armistice, but the difficulties solved at the few meetings of the Board showed that it would do much to relieve interdepartmental friction.[2]

V. The Rationing of Consumption.

In addition to deciding the priority to be enjoyed by direct munitions work, the Ministry had to try and discriminate among the mass of building schemes and factory extensions resulting from that work, and also to restrain private building activities which competed for materials and labour. This work will be considered in the following section, together with the arrangements adopted for rationing non-essential trades with the minimum of material required to keep them alive.

(*a*) Limitations Imposed by the Munitions Works Board.

By the beginning of 1917 building on a huge scale was going on all over the country, and State factories and extensions to contractors' works competed with each other for the dwindling supply of man power and materials. Critics of the War Departments urged that some of this building was unnecessary and wasteful and that urgent buildings

[1] See M.C./289. It held its first meeting on 18 September 1918. (D.M.R.S. 460 A; Hist. Rec/R/263/23).

[2] The scheme, as approved by the War Priorities Committee, the classification of work arranged and the permits and instructions approved by the Board are filed in Hist. Rec./H/620/6.

were often held up for labour or material which had been absorbed on less vital work. In order to remedy this state of affairs the Munitions Works Board, representing the chief departments interested, was set up (February 1917). The Board was charged with the duty of seeing that no unnecessary building was allowed to proceed, that such buildings as were sanctioned were carried out in the most economical manner both with regard to labour and materials (especially steel, timber, bricks and cement), and that all designs were criticised from the point of view of economy. No extensions or building work to the value of more than £1,000 were to be undertaken at any controlled establishment without the sanction of the Munitions Works Board.

The Board continued to work on these lines until the end of the war. From the beginning of 1918 it was helped in its work by a Works Construction Sub-Committee of the War Priorities Committee of the Cabinet, which considered all extensions involving £5,000 or more and decided the grade of priority to be given to each scheme, thus relieving the Munitions Works Board of the difficult task of holding the balance between the various Government Departments.[1]

When deciding priority questions on its own responsibility the practice of the Munitions Works Board was to refuse to allow any building scheme which was not strongly supported by the Ministry department or the Government Department interested in the extension.[2] Many schemes were rejected on this account, and many more on the ground that though useful, they were not vital. Other proposed new works were condemned on the ground that they could not be completed in time to be useful during the war, as in a London Electric Railway Company scheme for installing new plant, which the Munitions Works Board refused to sanction on the ground that a scheme which would secure the saving of 60,000 tons of coal per annum at the end of eighteen months could not be considered as urgent war work.[3] Priority for a copper tubing mill was refused because existing capacity was not being fully utilised owing to the shortage of labour.[4] Sometimes the Board adopted the method of criticising proposals from the priority standpoint, and referring them back to the Department in which they originated for further proof of their urgency,[5] and extensions were often forbidden because firms did not dilute their labour enough, or use night shifts.

The Board was reluctant to sanction public utility schemes, except in cases where they obviously assisted munitions production by supplying water, light, heat or power,[6] and was extremely critical of housing

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[1] During the final months of the war, schemes involving £1,000 or more had to be submitted to this Cabinet sub-committee (Munitions Works Board Minutes, 16/10/18), and a little later the War Cabinet ordered that no extensions were to be sanctioned unless they were immediately required for the purpose of winning the war. (M.C. 754).

[2] Munitions Works Board Minutes 15, 22 February; 5, 14, 22 March 1917, etc.

[3] *Ibid.*, 4,18, September, 1918.

[4] *Ibid*,, 14/2/17.

[5] *e.g.*, the Board doubted whether a scheme for a new national nitro-cellulose factory would give results commensurate with the money and labour involved. (*Ibid.*, 5/2/17).

[6] Munitions Works Board Minutes, 14/3/17.

schemes. It refused to accept certain housing schemes on the ground that there was no clear evidence that the accommodation was required for munition workers, and when this criticism could not be urged, as at Queen's Ferry, the Board was reluctant, on the grounds of economy, to sanction a scheme prepared on "model village rather than commercial lines."[1] In another case the Board suggested that it might be preferable to stop work on a certain aviation factory rather than to spend £60,000 in housing its workpeople, who refused to live in neighbouring villages because they "objected to being conveyed in lorries along narrow roads in the dark with deep ditches at the side."[2]

Expenditure on canteens and hostels, and welfare expenditure generally, was closely watched by the Board. Many plans were rejected as too extravagant, or too permanent in character, and were referred back to their authors for resubmission on a more modest scale.[3] The Board thought the erection of hostels had been "somewhat overdone" and that they were not fully utilised.[4] It also objected to labour being used in building recreation halls at hostels, but was overruled on this point by the Minister.[5]

In addition to eliminating in this way all unnecessary building, the Board enforced economy by detailed criticism of estimates and designs. In one or two cases the Board reported that the sites chosen were unsuitable, but its chief work was this technical criticism of plans and estimates with a view to economising money, man power or material. From its knowledge of average costs of construction the Board was able to disallow some estimates outright as too extravagant, and to suggest that competitive tenders should be obtained, or, conversely, to point out that costs had evidently been under estimated. Variations in design which enabled the estimates to be revised and reduced were suggested by the Board's surveyors, and plans were criticised in detail in the effort to save material. Some were rejected on the ground that no effort appeared to have been made to economise steel,[6] and the substitution of iron or timber for steel roofings, columns, window sashes, doors, and door framings, was made a condition of accepting the plans.[7] The use of reinforced concrete in lieu of steel was advocated by the Board during the first year of its existence, but this policy had to be given up later as this type of construction proved to be very slow.[8]

As the shortage of lead and of timber became more pronounced the Board suggested modifications in design. Lead was only to be used when there was no satisfactory substitute. The amount required to

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[1] Munitions Works Board Minutes, 19/2/17.

[2] *Ibid.*, 26/10/17.

[3] *e.g.*, 15 March 1917. In one case estimates were reduced from £31,000 to £18,000. (11 September 1918).

[4] Munitions Works Board Minutes, 27/6/17.

[5] *Ibid.*, 26/3/17, 16/4/17.

[6] Before it became scarce the use of shell discard steel was insisted on.

[7] See, for instance, Munitions Works Board Minutes, 26 February, 2, 6, 22 March 1918.

[8] *Ibid.*, 1, 5 May, 5 June, July 1918. Cement was controlled by the War Office Contracts Branch and there were many complaints of delay in releasing it.

carry out any building and the amount that would be recovered as scrap had always to be approved before plans were passed. Timber was to be used sparingly, and home grown timber in preference to imported timber. The Board often suggested substitutions, as of asbestos sheeting for corrugated iron, bitumen for lead, and so on. Another way of economising was to prune schemes of all ornamental or unnecessary features—clock towers, boundary walls, elaborate office accommodation and so on—and the vigilance of the Board extended even to items like the provision of marble top tables in a canteen, which were condemned as extravagant.

Throughout, the Board showed great anxiety to prevent firms from building permanent extensions where cheaper temporary buildings were to serve the purpose, and the fact that the Board had power to recommend the amount of contribution to be given by the State by means of "writing off" allowances[1] enabled it to economise labour and material as well as money by refusing to pass any building plans that were too substantial for their purpose (permanent extensions in the guise of canteens) and schemes which were partly of a post-war character.

The actual work of construction was watched by the Board's surveyors, who certified expenditure, and made weekly reports as to progress. A large number of cases in which expenditure exceeded estimates were considered, and the Board decided that no notice should be taken of small excesses, but that extravagance was to be penalised by disallowing part or all of the excess expenditure.

Generally speaking, the authority of the Board was accepted without friction over a very wide field. The chief extensions during the last year of the war were for aeroplane construction, shipbuilding and the production of steel, tanks and gas for chemical warfare, but the supervision of the Board extended to shipbuilding yards, collieries, sewage works, gas undertakings and so on. There were a few instances of firms who began to build without sanction and these were referred to the Building Works Section for disciplinary action, which meant prosecution for carrying on building work without a licence. It may be noted that the chief offenders were the managers of the national factories, and in these cases the Board had no power to penalise the disregard of its authority.[2]

(*b*) Control of the Building Trade.

Pressure of circumstances forced the Ministry to undertake control of the building trade at an early date, but control was postponed as long as possible and then assumed with reluctance.

The competition of Government contractors for building labour in the autumn of 1915, which led to the payment of wages higher than the district rates, and to a general shifting of labour and waste of time and money, was met by the appointment in the Ministry of Munitions of a Building Labour Committee (October 1915) which endeavoured to

[1] The strictly financial aspect of the Board's work is considered elsewhere, (See Vol. III, Part III).

[2] Munitions Works Board Minutes, 1, 15 February 1918.

control wages in the building trade so far as Government Departments were concerned,[1] and by the decision to stop all non-essential building (February 1916). Under Defence of the Realm Regulation 8.A.(6) work on the building of the London County Council Hall and at Staines Reservoir was stopped by order of the Minister of Munitions, and similar action was taken with regard to additions to banks and factories and the construction of new cinemas, though in the absence of any general Order prohibiting building work, the action of the committee was inevitably unscientific and irregular in its incidence.[2] Technical advice was also needed as to the stage at which work on buildings could be stopped without danger of collapse or serious damage to the work already done, and in April 1916 Mr. (later Sir Ernest) Newton, then President of the Royal Institute of British Architects, became technical adviser to the Ministry.

At this point the growing shortage of constructional steel, added to the shortage of building labour, made a general restriction of building desirable. Regulation 8.E. under the Defence of the Realm Act was therefore issued on 14 July 1916. This regulation forbade the undertaking or completion of any building contract of more than £500 in value, or involving the use of constructional steel, unless carried out under a Government contract or by a local authority, or unless licensed by the Ministry of Munitions. A special section of the Ministry which already dealt with building labour (the B. W. Section) considered applications for building licences under this regulation. The general principle adopted was that no new work should be allowed unless it was undoubtedly necessary for the prosecution of the war and had been recommended by the Priority Committee, or was of special public utility, on which point the Local Government Board was the arbiter. Private work of any importance was prohibited, licences being granted only for work which did not exceed £700 in value, and which was being carried on in the country, employing elderly workmen whom it was difficult to transfer to Government building work.

Some twenty per cent. of the applications for building licences were refused,[3] and certain building firms were prosecuted and fined for building without licence from the Ministry. Protests were made by the building trade, some sections of which were already hard hit by the war, as most of the factory construction was done by large firms of contractors, and a Parliamentary Committee under the chairmanship of Mr. R. W. Prothero was appointed to enquire into the administration of Regulation 8.E. Their report confirmed the necessity of the existing restrictions and indicated that there might have to be some further diversion of labour and material from private to national work. The committee was satisfied that in most cases no hardship whatever was inflicted on the workmen displaced, owing to the great demand for their services in other directions.[4] The same system of issuing building

[1] For details of the committee's work, see HIST. REC./H/321/2.
[2] *Ibid.*, p. 14.
[3] HIST. REC./H/321/2, p. 18; (Printed) *Weekly Report* No. 52, XI (29/7/16).
[4] For a further discussion of the effect of the licensing system upon building labour, see HIST. REC./H/321/2; HIST. REC./H/321/3; M.W. 124281/23; M.W. 51873/55.

licences was therefore continued, and control became more stringent as the shortage of material and labour increased. Buildings destroyed by fire or enemy action were not rebuilt unless of national importance, but the entire prohibition of all building except by licence, though proposed by the War Cabinet on several occasions, was not insisted upon.

The transference of the B.W. Section to the Ministry of National Service (1 March 1918) did not affect the character of its work, and private building, except in Ireland,[1] was curtailed within the narrowest limits until the Armistice, when freedom was at once restored to the trade.

In the hope of economising building labour and restraining Government Departments from beginning more building work than could be carried to completion, the Ministries of Labour and National Service submitted to the War Priorities Committee an elaborate scheme for rationing Government Departments in their building activities and allocating their contracts at a standard rate of wages through a federation of the trade (2 November 1917).[2] This elaborate scheme, however, was not carried out. Though the creation of the Works Construction Sub-Committee of the War Priorities Committee met one of the points urged by its promoters, it was found impossible to reach a general working agreement with the national federations, though the placing of contracts through local federations, was tried on a small scale by certain Departments at the instance of the War Priorities Committee (1 January 1918). The War Priorities Committee therefore handed the scheme back to the Ministry of National Service, urging them to effect a settlement (6 March), and the scheme died a natural death.[3]

In the same way it became necessary to curtail all railway development that was not immediately required for war purposes, and by an Order of 14 July 1916 all railway construction was prohibited except by licence from the Ministry of Munitions.[4] The Ministry urged that the building of locomotives should be restricted in order to economise steel for industrial purposes, and that passenger traffic should be limited.[5] There was great activity in the construction of sidings for munition factories, magazines, storage depôts, iron and steel works, docks, etc. to carry military and munitions traffic,[6] and in the last year of the war, a large scheme of railway construction, designed to faciliate the diversion of traffic from East to West coast ports, should the exigencies of submarine warfare make such a diversion necessary, was endorsed by the War Priorities Committee (10 June 1918), high priority for material and for labour being awarded on the understanding that the railway material required by the Army in France should not be interfered with.

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[1] M.W. 32870.

[2] M.C. 463.

[3] M.C. 463.

[4] There were instances, however, of railway companies evading this restriction of construction. (C.R.V./Gen/1784).

[5] (Printed) *Weekly Report*, No. 68, XI (18/11/16).

[6] The Ministry of Munitions alone authorised the construction of 376 sidings involving an expenditure of over £1,700,000. (Hist. Rec./H./1122/1.)

Many of the largest tramway companies found themselves in serious difficulties towards the end of the war.[1] They had not been able to obtain steel to replace worn lines, and in the autumn of 1917 the replacement of large sections of their track could no longer be postponed without danger; they had difficulty in retaining their labour, and financially were in no position to compete for it by paying very high wages. Some of the largest undertakings pressed for Government control in the hope of escaping from some or all of these difficulties. Though deeply interested in maintaining the efficiency of services which transported large numbers of munitions workers, the Ministry of Munitions was not enthusiastic about control. It recognised the necessity, however, of allocating a minimum amount of steel for the maintenance of municipal and privately-owned tramways,[2] and urged the Board of Trade to appoint a Tramways Committee which could prepare a schedule of minimum demands, make arrangements for melting down worn out rails, and removing rails from non-essential routes. This suggestion was accepted, and at the beginning of November a Tramway Committee, representing municipal and private undertakings, was set up,[3] which sent a representative to meetings of the Railway Priority Committee at the Ministry.[4]

(*c*) The Rationing of Civil or Non-Essential Industries.

The arrangements for preserving non-war industries were interesting. Only about ten per cent. of the material dealt with by the Priority Department was available for ordinary civil industries, but machinery was devised by the Ministry for distributing that ten per cent. in such a way that existing industries, not directly essential to the conduct of the war, should be kept alive until peace restored to them full freedom of action. A Priority Advisory Committee[5] was set up to enquire whether it was in the national interest to allow any trade enough material to keep it going, and if so whether material for any home orders except war work should be provided, for what countries export orders should be allowed and so on.[6] The committee decided that all trades which desired it were to be heard through representative associations, and that no firms were to be dealt with individually. All traders had to disclose the amount of stocks they held, the amount of material they would require for a six months' (later a three months') programme, and the committee adopted the general principle that home trade was to give way to export trade, and that export trade with countries where the exchange was unfavourable was to be preferred

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[1] M.C. 169.

[2] The Steel Allocation Committee had decided that no steel could be spared for this purpose, September, 1917.

[3] M.C. 169.

[4] January 1918. (C.R.V./Gen/1564).

[5] See above, p. 44, and Appendix iv.

[6] Minutes of Priority Advisory Committee, 31/3/17. After December 1917, the committee was allied with the Public Services Committee set up by the Cabinet to secure the maintenance of gas, electric power, water and tramway undertakings, and was known as the Industries Committee.

to export trade with other countries.[1] When the committee had decided upon the ration to be allowed, it appointed a rationing authority for the trade, usually a firm of chartered accountants. The actual permits for the release of the materials were issued after consultation with the supply departments, who with few exceptions, accepted the committee's recommendations. Representatives of trades threatened by the withdrawal of material, attended before the committee and stated their case, the usual line of argument being that it was desirable to prevent British trade being captured by foreigners, that men above military age were being employed, that the factories were not suitable for conversion to munitions production, and that scrap or other material unsuitable for munitions production was being used. By way of illustration, the case of the brass founding industry, which used these and other arguments before the committee when appealing for a ration of copper, may be quoted. The committee was not impressed; they thought that men had been badged to avoid military service, and that if the trade was stopped they would be available to meet the great demand for munition workers in the Birmingham district. The committee pointed out that the diversion of copper from munitions to bedstead ornaments or even to gas taps and joints was inexcusable, and refused to grant licences even for the export branch of the trade.[2]

On the other hand, a ration of copper was allowed to the electrical trades for export to the Allies (through the Commission Internationale de Ravitaillement) and the Dominions and to all neutral countries (except Spain), the reason for this comparative leniency being that the copper represented a very small proportion of the articles exported, which were valuable and specially beneficial to the exchange. The open permit for copper allowed by the Copper Section to the industry for domestic lighting in the United Kingdom was, however, cancelled as 300 tons of copper had been used in three months, and in future the trade was limited to the amount required for repairs and maintenance. The committee also advised the issue of permits for the importation of small amounts of copper wire for piano manufacturers, as the consumption of copper was very small in proportion to the value of the export trade for which alone it was to be used.[3] The use of substitutes wherever possible was insisted on, especially the use of wood, glass or *papier maché* containers instead of tin plate, which was to be kept as far as possible for packing tea, Manchester goods, paint and tobacco. Sometimes the substitute recommended was unobtainable; the mattress trade was allowed a small ration of wire as the substitute, straw, could not be got, "on condition that the sale of mattresses was not pushed and that hospital and Government orders were given preference," and the pottery trade was allowed a

[1] The Treasury gave the following list of countries to which export was desirable, in a descending scale:—United States and Cuba, Argentine, Scandinavia, Holland, Dutch East Indies; while export to France, Italy, Portugal, Brazil and Russia was not desirable.

[2] Minutes of Priority Advisory Committee, 6, 13 March 1917.

[3] It appeared later that the home trade was being carried on on a very large scale, 3,388 pianos being sold at home and only 320 exported within the same period.

small ration of lead, as the importation of the substitute, borax, had to be curtailed owing to its bulk, and export of pottery to America was very profitable. Substitution was often too expensive and laborious as in the case of waxed paper, the proposed substitute for lead capsules. The shortage of lead was very serious. The keels of yachts were being commandeered and the roofs of churches might have to follow. No trade which consumed large amounts of lead, like the lead pipe trade, could be supplied, and the stringency was so severe that the manufacture of cartridges for shot guns was forbidden, with the exception of the small quantity required by farmers for the protection of their crops, while no paint was to be made containing more than 3 per cent. of lead. The prohibition of the use of lead for capsules led to a great outcry later, when it was discovered that Dutch capsules were being imported made of lead which had been exported from the United Kingdom[1]. Discrepancies of this kind were felt as a genuine grievance by industry. Another case of the kind—the importation of electric batteries from the United States when material had been refused to manufacturers of batteries at home—led the Advisory Committee to remonstrate with the Board of Trade.

The influence of the Board of Trade representative on the committee was naturally directed towards securing material for trades which would otherwise have been passed over as non-essential. Thus they obtained linseed oil for velvet dyers as well as for floor cloth makers, and supported an application for machinery for restarting the manufacture of Gillette razor blades in Great Britain in lieu of importing them from America, and prevailed on the committee to allow steel for bedstead makers in order to support a valuable export trade. The Steel Allocation Committee, however, refused to honour this recommendation and the question was referred to the General Services Committee of the Cabinet. In its efforts to enforce economy the committee often stipulated that a certain percentage of the metal allocated to a trade should be returned as scrap.[2] The attention of firms who had been refused a ration of tin plate was directed to the utilisation of old tin containers which might be bought freely and to alternative forms of packing. By April 1918 most of the salvage tin available had already been allocated in this way.

Manufacturers who had not been in existence before the war were not normally allowed supplies of rationed materials, except in a few cases, *e.g.*, the manufacture of metalled steel sheet, of tin foil, of toys, of patent leather and of malleable iron piping, where a new trade had sprung up to replace a German or American industry.

When the committee had information that a firm was in arrears with its Government work, the threat of cutting off their ration for civil work was used, and this was a useful method of persuading them to overtake these arrears in lieu of continuing more remunerative but less essential civil work.[3]

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[1] Priority Advisory Committee Minutes 22/11/17.

[2] A certain proportion of the ration was usually to be taken in the form of scrap and waste.

[3] Minutes of Industries Committee, 13/6/18.

Finally, in 1918, when the shortage of materials became most acute, the policy of allowing supplies of material for export trade in preference to home trade had to be reversed, and the dwindling supplies were kept to meet a proportion of the home demand, which became more intense with the diminution of stocks. A selection rather than an enumeration of the trades affected, which is a useful indication of the extent to which the shortage of materials brought non-war industries under State control is given in the following list: men's felt hats, millinery, hairpins, hooks and eyes, buttons, thimbles, pins, needles and safety pins, corsets, umbrellas and rubber heels, spectacle cases and jewellery, sewing machines, washing machines, domestic tin ware, cast iron hollow ware, floorcloth, bedsteads, clocks, toys, perambulators, bicycles, pianos, gas stoves, gas and electric meters, boilers and all plumbing supplies, locks and latches, wire, screws and nails and coffin furniture, pottery, paint, colours and varnish, printing, dyeing and cleaning, calico printing, velvet finishing, organ building, the cutlery trade, the edge tool trade and the chemical trade.[1]

Few important civil industries escaped from the necessity of applying to the Industries Committee for a ration, and the action of the committee in cutting down formerly prosperous trades to a bare maintenance level led to real hardship. Experience of the irksomeness of State control accumulated in trades which saw their export trade slipping away and their home trade strangled by lack of materials and, by a natural confusion of thought, the hardships occasioned by the shortage of materials were attributed to the State control which this shortage necessitated.

Little criticism, however, was directed against the committee's methods, which seems to have been recognised as generally satisfactory. The chief grounds of complaint came from individual manufacturers who resented the necessity of forming trade associations and acting through them, and of disclosing to such associations figures of their stock and turnover.

On the other hand, some of the allocations made by this committee were strongly criticised by the Priority Department, which refused to issue the necessary certificates on the ground that rations of scarce metals allowed to non-essential trades like organ-building and toy making would reduce the amount available for railway work and water supply, which had been cut down to the minimum. Moreover, trades of much greater importance, like the motor trade and the general engineering trade would expect similar treatment, which would be impossible in view of their huge demands upon labour and material.

The argument as to the value of the export trade also needed careful scrutiny in view of the fact that much of this trade was with the Allies who were already deeply in our debt, while the effect upon our trade reputation of marketing goods made under war conditions

[1] For a list of the trades rationed and of the rationing authority, see HIST. REC./R/263/23.

was, in many cases, dubious.[1] Moreover, the United States would view with grave suspicion any attempt to bolster up British export trade by allocations of scarce materials exported by the United States for war purposes only.

The outcome of the committee's work was that the trades rationed received about one-third of the metals they consumed in 1913. Thus on the basis of a consumption of steel, iron, tin, zinc, copper and brass, aluminium, lead and antimony totalling 154,340 tons per annum in 1913, the trades were allowed quarterly rations equivalent to an annual consumption of 52,713 tons, while to the least essential trades no ration at all was allowed.

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[1] The United States merchants were alive to this danger and were marking many of their exports "War Time Finish."

CHAPTER V.

REVIEW OF DECONTROL AND LIQUIDATION OF STOCKS.[1]

I. Release of Materials.

At the time of the Armistice the bulk of the essential materials required for war production were controlled, not only by the British Ministry of Munitions and other Government Departments but by inter-Allied organisations. Decontrol was thus governed by international as well as national considerations. The Inter-Allied Munitions Council dealt, through various committees, with wool, cotton, hides, leather, tanning materials, timber, petroleum, flax, jute, hemp, coal, coke, nitrates, chemicals, steel and non-ferrous materials. The Council was, however, concerned solely with control for war purposes, and as the American delegate had no mandate to deal with any peace problems in connection with materials, the Council could no longer serve any useful purpose after the Armistice, and was dissolved. It was, however, recognised that some inter-Allied co-operation as to control over prices and the importation of materials would be desirable, and the Supreme Economic Council was formed to deal with control in its international aspects.

The reaction against all forms of control was strong both in England and America, but additional force was lent to the movement in the States by the desire to cut loose from all European entanglements, and this circumstance prevented inter-Allied co-operation to the full extent which was desired by the other Allies. Thus an agreement made in November between America, Great Britain, France and Italy, to set up a Leather and Hides Executive was frustrated by the violent and widespread revolt against Government control in the States. For the same reason the Nitrate Executive was dissolved immediately after the Armistice. The British Ministry of Munitions was opposed to the continuance of inter-Allied control of copper, as it was felt that supply would soon exceed demand, and since British firms refined but did not produce copper, price fixing might tend to prejudice the industry, while official control would hinder the rapid resumption of trade.[2]

In Great Britain two schools of opinion arose as to the policy of decontrol. Labour opinion was in favour of the continuance of Government control as the only means by which the public could be protected against extortionate prices. Trade interests on the other hand were almost unanimously in favour of the re-establishment of

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[1] The relaxation of War Office control is dealt with in the Supplement to this Part, For further details with regard to liquidation see Vol. II, Part I. Supplement.

[2] C.R.V./Gen/2729.

private dealings with the least possible delay. The general policy of the Government was to remove control as quickly as possible, though it was recognised that, as the artificial state of many basic industries was due to Government control during the war, control would have to be continued until conditions became more normal. With regard to foreign trade, the attitude of the British Government was to encourage manufacture for export by releasing materials at economic prices and to make no attempt to secure liquidation of Government stocks at very high prices, to leave manufacturers freedom in foreign markets, and to retain merely the right to fix reasonable prices in Allied markets and to ensure that reasonable quantities of the country's exportable surplus should be made available in those markets.[1] The necessity for maintaining the blockade of Germany for some months after the Armistice was a factor which necessitated continued control of trade with the Border neutrals.

Great Britain was the only country among the Allies in which the iron and steel trades had been placed by war control on a wholly artificial basis, and one of the foremost problems of the reconstruction period was to re-establish these important industries on an economic footing. Until this was done the whole engineering industry rested on an unstable basis. Steel prices in Great Britain had during the war been stabilised considerably below the economic level. This was done mainly with a view to avoiding the necessity of altering contracts for finished munitions and had been accomplished by subsidies on freight, ore, pig iron, limestone, etc. Though freight conditions were expected soon to return to normal, the other items in the subsidy were practically all due to wages and their effect would not immediately disappear. An immediate restoration of economic prices would have caused dislocation in the trade, for the changes would have affected the sliding scales of wages, and any serious disturbance of wage rates in the iron and steel industries was likely to have a repercussion throughout the whole of the industry of the country. Moreover, it was probable that a large increase in prices would have checked demand and curtailed export trade.[2]

After considerable discussion with the trade it was decided, early in December, that the subsidies should be removed in two stages. Those applicable to steel were removed on 31 January 1919 when a revised schedule for maximum prices came into effect. Those applicable to pig iron were continued until 30 April, when all subsidies ceased. These arrangements did not apply to the tin plate and galvanised sheet trades as they had agreed to contract out of the subsidy. These trades, however, arranged an agreed price for home markets, and for export to the Allied Governments. Otherwise they were free as regarded prices, but priority was insisted upon for such part of the output as was considered necessary for home and Allied needs. The export price for steel was fixed by the Government to include the full amount of the subsidy, and a drawback was levied on exported iron and steel to correspond to the difference between home and export prices.

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[1] M.C. 829.

[2] See Vol. VII, Part II, Chap.VI.

There was some question whether the Priority Department would be able to cope with the scramble for steel on a subsidised basis, and it was suggested that the position might be met by placing orders for standard articles with steel works up to their full output.[1] This would, however, have had the disadvantage of preventing firms from accepting commercial orders, and eventually arrangements were made in consultation with the trade to secure an equitable distribution of pig iron and steel, while the subsidies were continued by means of a standing committee of Iron and Steel Manufacturers. In order to prevent the accumulation of stocks, with a view to sale at high prices after the subsidies were removed, an Order was issued on 7 January 1919 to the effect that no one might, without, permit increase his stock of iron or steel, or the two together, by more than 100 tons above that held on 31 October 1916 or 31 October 1918, whichever was the greater. These permits were issued freely to all applicants, on condition that a certain sum per ton equivalent to the amount of the subsidy was paid on all excess stocks.

Materials of which the supply was ample were decontrolled very rapidly during November and December in order to enable British manufacturers to hold their own in foreign markets. Immediate steps were also taken to release stocks of materials for the same purpose, and to release from control, machine tools and plant without which the reversion to peace industry could not be made. All restrictions on the purchase and manufacture of machine tools were removed in November, and contractors with plant belonging to the Ministry were at liberty to use it for civil work, on notifying the local superintendent engineer of their intention, the only condition being the payment of reasonable hire if the contractor did not intend eventually to buy the machine. The Minister desired that manufacturers of machine tools should as far as possible give preference to plant required to enable contractors to give employment to a maximum number of workmen. Various other Control Orders limiting manufacture, *e.g.*, of wire rope, forgings and castings, motor engines, aeroplanes and aero-engines were also withdrawn during November. On 14 November the Minister gave notice that restriction on the manufacture and the use of certain materials would be relaxed without delay, and in the meantime manufacturers were at liberty, subject to the existing Priority of Work Order to use at once, whether for stock or otherwise, any iron, steel or non-ferrous metals already in their possession, and to accept any orders for manufacture subject to existing Orders as to price. On certain terms Ministry materials held by contractors could also be used.[2] On 25 November 1918 pending the withdrawal of existing Orders, stocks of non-ferrous metals were released for general industrial purposes without special priority permits. From 23 December iron and steel as well as non-ferrous metals could be ordered and supplied without priority classification, though special priority was still retained for urgent national and Allied requirements, and exports were subject to licence in view of the continuance of the blockade. Supplies of industrial alcohol

[1] Raw Materials Committee Minutes, 12/11/18. [2] Hist. Rec./R/680/4.

and glycerine were released in December, and Control Orders were suspended in the case of shellac, calcium carbide, benzol, naphtha tar, acetic acid and chlorine. Large stocks of acetic acid and glycerine were held by the Government and as there were also large reserves in America, the relaxation of control involved the risk that the British Government might be undersold. In spite of this it was decided to relax control, and trade in these materials became entirely free.

Besides iron and steel, control was retained for a time over phosphate rock, certain acids and fertilisers, pyrites, and rosin. Control over fertilisers was retained at the request of the Food Production Department, because they were subsidised, and care had to be taken that they were fairly distributed. This necessitated the continuance of control of sulphuric acid,[1] superphosphates, ammonia and nitrate of soda. A decision as to the decontrol of ammonia was complicated by the fact that as prices were controlled it paid the manufacturer to sell ammonia compounds rather than sulphates, though the latter were urgently required for fertilisers. Fertilisers were finally decontrolled at the end of May 1919 and after the release of formal control, all questions relating to distribution were dealt with by the Department of Agriculture.[2] In the case of rosin, though the original reasons for control no longer existed, it was necessary before relaxing control to ensure that purchasers were able to obtain all the rosin they required through the usual channels. The Minister therefore retained the existing system by which the Rosin Distributors' Association disposed of Government stocks. All restrictions on the import of rosin from Spain and Portugal were removed, but licences were required for supply to consumers. Rosin was finally decontrolled on 1 May 1919.

A certain degree of control over platinum was retained by limiting sales. This was necessary owing to the cessation of output from Russia, and to prevent a shortage for industrial purposes. The French and American authorities liquidated their stocks rapidly, but the Minister thought it advisable to protect essential trades during the period of shortage which was bound to continue until production in Russia revived. His policy was therefore to limit sales to a maximum of 2,000 oz. a month, giving preference to home consumers.[3]

After the Armistice there was no longer any necessity for the Department of Aircraft Production to secure flax for its own needs, but it had to fulfil its engagements with Irish farmers and to complete the purchase of the 1918 crop at a fixed price. The probability that a large part of the acreage would be used for other purposes than flax growing unless the farmers were guaranteed a price for the 1919 crop, and the desire to maintain a newly developed industry led the Government to decide that this guarantee should be given. This entailed the continuance of existing restrictions on the import of foreign flax. Since the requirements of the Government for flax would be fully met out of existing stocks, the War Office, Air Ministry or Ministry of Munitions had no longer any interest in control, and the responsibility for administering the purchase and disposal of the 1919 crop was therefore transferred to the Board of Trade as from 1 April 1919.[4]

[1] P. 139. [2] *Ibid.* [3] M/Demob./167. [4] Sec./Gen/976.

It was decided in February 1919 to retain the control of mica for the present, since it appeared probable that for some time demand would exceed supply, and it was necessary to safeguard supplies for essential purposes. During the war London had become the chief mica market for the world, and it was of great importance to the British electrical industry that the market should neither be captured by America nor revert to Germany. The magneto industry especially was dependent on supplies of high quality mica.[1] The supply of magnetos before the war had been virtually monopolised by the Bosch Company of Stuttgart, and in view of the importance of this industry for all forms of transport driven by petrol engines, it was regarded as a key industry. The Ministry therefore recommended that post war control over mica supplies in India should be established to ensure supplies of guaranteed size and quality. With this end in view the Minister approached the Indian Government with proposals involving continued control of sorting and grading in India, and the prohibition of export except to the United Kingdom, with the exception of limited quantities of splittings, for a period of years. The Ministry also proposed to maintain for a short time the mica Control Order of April 1918 under which purchase and use were permitted only under licence.[2] These proposals did not meet with the approval of the Treasury, and the Government of India was unwilling to prolong the system under which export was permitted to the United Kingdom only, unless the British Government would guarantee the purchase of the whole output, and favoured an alternative whereby export should be permitted freely to British and Allied destinations subject to control of re-export from Allied countries as long as there were restrictions on the trade in mica with enemy countries.[3] The responsibility for the supply of mica was taken over by the Board of Trade soon afterwards; and the Ministry was therefore unable to give any guarantee for the purchase of the whole output and had at the instance of the Indian Government to agree to temporary free export to foreign countries, pending arrangements to be made by the Board of Trade. In handing over control the Ministry advised that control under the Order of April 1918 should be retained until the end of June,[4] but the Order was actually suspended on 30 May 1919 since, when export became free, control of the use of mica became impracticable.

The question of the price at which materials owned by the Government should be sold was a difficult one. If the Government had sold these materials at a price which would cover their cost, British trade would have been injured owing to the fall in prices in foreign markets. Failing any international agreement as to prices, the best course seemed to be to supply materials to British trades at a low price in order to assist the resumption of export trade. It was therefore decided in December 1918 that Government stocks should be placed at the disposal of industry at the world's value from time to time. It was believed that any loss incurred in selling Government stocks below cost would be more than counter-balanced by the re-establishment of

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[1] Hist. Rec./R/264.2/7.
[2] CRV/I/279.
[3] DDGM. 1179.
[4] CRV/I/279; D.B. 4/8.

trade. The market for non-ferrous materials, for instance, was thrown open, and the London Metal Exchange once more become effective. It was hoped that the opening of the Metal Market would attract business to London and restore the supremacy of the market in the metal trade. The result of selling in the United Kingdom at world's prices was to render metals available to the British consumer at a price slightly below that of import as freight and wharfage charges were saved. In order that the metallurgical trades might know the exact position, particulars of Ministry stocks of the most important non-ferrous metals were published month by month. Orders relating to prices of tin, copper, spelter, brass, lead and cupro-nickel scrap were suspended on 11 December, though not actually revoked, and sale prices were published from time to time. By the end of February metal prices had been steadily reduced, but as the British Government's prices quickly became known throughout the world, American and other merchants undercut them so that the Ministry could sell only for immediate delivery. It was felt that if this policy was continued little Government material would be sold until a very low price was reached, when it might all be sold and an artificial shortage be produced. The only possibility seemed to be to follow the finer fluctuations of the natural market, and the publication of prices was therefore discontinued. The Non-Ferrous Materials Department were from that time free to quote for any enquiries in respect of copper, lead, spelter, rosin and shellac. Sales on these lines proceeded somewhat slowly, and the large quantities of scrap to be disposed of naturally affected the rate at which virgin metals could be realised.[1]

The selling price of copper was at first fixed at £137 per ton for electrolytic copper, but it was soon found that this price was so high as to impede manufacture, and after consultation with the trade, £125 per ton was agreed on as a reasonable price in order to encourage trade,[2] the new price corresponding to the American price of 26 c. per lb.

The Ministry was in certain instances accused of disposing of stocks with undue rapidity. During the early months of 1919 complaints were received from shippers of the amount of shellac that was being put upon the market. They wished to limit Government sales to not more than 1,000 cases. The Ministry, however, refused to agree to this, as there were indications of an attempt at cornering supplies and driving prices to an unreasonable level. If there had been any limitation on the amount of its sales, the Ministry would have been unable to defeat the ring or corner.[3]

The policy of disposing of Government stocks of many materials through the ordinary trade channels was adopted. In some cases (*e.g.*, glycerine) manufacturers themselves sold Government stocks *pari passu* with their own production. The whole stock of alcohol, calcium carbide and cotton waste was distributed through the usual trade channels at the best price obtainable, and in November 1918

[1] M./Demob./167.
[2] Raw Materials Committee Minutes, 6, 11 December 1918.
[3] CRV/I/279.

the Ministry expressed themselves willing to pay brokers and recognised merchants of non-ferrous materials a commission of ½ per cent., subject to cash payment for the materials. Ministry stocks of aluminium and platinum were almost entirely liquidated through the trade on a commission basis, the residue being sold to the trade outright.

The policy of disposing of Government stocks through the ordinary trade channels, had the double advantage of restoring trade, and of relieving the Government of the cost and trouble of disposal. Merchants were eager to re-establish their foreign connections, and were able to do this by disposing of Government stocks on commission. They were also glad to be rid of the potential competition which the existence of large stocks provided. In some cases firms were remunerated by a percentage on sale, the rate varying with the material dealt with. In other cases they were paid a fixed sum per ton of materials sold. For nitrate of soda and wolfram each contract made by the agency firm required approval by the Department, but in general, firms were free to make the best arrangements they could. Cotton was sold on a commission of ½ per cent. and expenses, but as the agents did not guarantee the payment of sums due from buyers an officer of the Department watched these sales on behalf of the Ministry.

This method of disposal was increasingly used as the amount of material declared surplus increased, and quick disposal became of more importance. The whole remaining stock of aircraft, and of mechanical transport was disposed of by this means, as were large amounts of ferrous and non-ferrous scrap. Notable instances of disposal by this method were various salvage dumps in France and Belgium. Great difficulties were encountered in dealing with these dumps owing to lack of expert knowledge of classification on the part of Army and Ministry employees. It was felt that the professional scrap merchants' knowledge of markets, and of the value of second-hand materials, as well as of the tools and plant required for utilising it, would probably secure much better prices than would be obtained by disposal through the Disposal Board's officers,[1] and a number of dumps, including the important "floating dump" at Zeneghem, were disposed of by this means.

With regard to machine tools each individual firm in the trade was asked to act as a selling agent for the Ministry for machine tools having a post war value, on a 12½ per cent. commission basis. Liquidation of all machine tool contracts was carried out on these lines.

II. The Use of National Factories for Industrial Purposes.

The post-war use of the national factories which had been set up during the war was a question of considerable importance in relation to the restoration of industry. Some 250 establishments had been worked by the Ministry for the production of articles of all kinds required for the prosecution of the war. A number of these reverted to their pre-war owners and uses on the cessation of hostilities; some were required temporarily for storage and other purposes; while it

[1] D.B. 4/40.

was originally proposed that about 20 should be permanently retained under State control as a nucleus for munitions production.[1] There remained about 85 factories which were considered suitable for industrial purposes, and the fate of these was the subject of considerable controversy.

In January 1919 the future of all the national factories was considered by the Cabinet, and it was decided that the Ministry should proceed with the sale of these 85 factories, giving preference, other things being equal, to trade unions, co-operative societies and local authorities. Representatives of labour were pressing the Government to retain certain of the factories under their control for the production of articles of commerce, in order to absorb unemployed labour. It was recognised, however, that if firms were threatened with Government competition, the extent or force of which it would be impossible to gauge beforehand, they would be discouraged and the recovery of industry would be checked. Moreover, as a certain degree of control was necessarily retained over materials, a bias in favour of the State factories might be suspected. The Cabinet ruled, therefore, that there was to be no competition between the State and private enterprise in the manufacture of articles of general trade. At the same time, however, they authorised full investigation of the possibilities of manufacturing articles of which the Government would be the sole buyer, with the stipulation that no sales department should be set up in connection with a national factory.[2] A list was accordingly prepared of articles of which the Government were regular purchasers, and certain factories were indicated as being suitable for various purposes. The box and aeroplane factories, for instance, were considered fit for the manufacture of window-frames, doors, furniture, etc., in connection with the Government's housing schemes.[3]

Investigation showed that the number of articles of which the State was the only buyer was so small that their manufacture in State factories would be most uneconomical, since it would be possible to keep factories at work on Government account only by manufacturing a great variety of articles in the same factory. Under such conditions costs of production would be high as compared with trade costs. Generally speaking, it did not appear that there was any satisfactory middle course between taking over a whole industry to be run as a Government monopoly and the system of purchasing Government requirements from the trade. Any intermediate course missed the advantage on the one hand of a monopoly, and on the other of economic production on a big scale. On these grounds, the policy of retaining any national factories save those required for the manufacture of armaments, and temporarily for storage and breaking down purposes, was definitely rejected, and the Ministry was authorised to proceed with the sale of factories to private individuals. This was thought to be the most expeditious means of restoring the factories to peace industry and creating a demand for the labour displaced from munitions production.

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[1] For further particulars, see Vol. II, Part I, Supplement.
[2] Minutes of the Co-ordinating Committee, 10/1/19. (HIST. REC./R/1000/61).
[3] HIST. REC./R/1122/20 (C.C. 79).

At the same time every facility was given for the acquisition of factories by labour organisations wishing to run them on co-operative or co-partnership lines. The Labour Co-Partnership Association and Co-operative Productive Federation had in January, 1919, put forward definite proposals for the operation of all such national factories as were suitable for industrial purposes on a profit-sharing basis.[1] After considering the scheme, the Minister decided that the Ailsa Craig National Projectile Factory should be made available for an experiment on these lines, in view of the fact that its general manager, Mr. A.W. Beuttell, had been the chief promoter of the scheme. Under the original scheme suggested by the Association, capital was to be supplied by the Government, but as this was contrary to the decision already taken, and difficulties of a constitutional nature precluded the financing and operation of the factory by trade unions, the scheme was to be financed privately, either from the usual sources, or from the ranks of labour. Pending the formulation of definite proposals for the sale or lease of the factory, it was continued as a national factory for the repair of motor vehicles. By May no definite arrangements had been made, and as the Minister did not feel justified in continuing Ailsa Craig as a national factory unless there was a definite prospect of its being taken over on a satisfactory basis, Mr. Beuttell was pressed for a decision.[2] Eventually, difficulties in making the necessary financial arrangements caused the abandonment of the scheme.

The nearest approach to State trading carried on after the war was the Motor Transport Repair Depot at Slough. This venture has both been praised as the most commendable undertaking of the post-war Ministry, and condemned as the worst. The Slough depot was planned in 1917 for the immediate purpose of supplying a fully equipped repair shop large enough to deal not only with all motor vehicles from home units, but with those from France in excess of repairing capacity there, as a storehouse for spare parts, and a store for vehicles awaiting repair. It was also planned as a provision for the repair and storage of post-war stocks of mechanical transport, as a general repair shop for the post-war Army, and as a central depot for the co-ordination of all the mechanical transport requirements of the Government. The inadequacy and unsuitability of the existing storage accommodation and repair facilities, and the necessity of a central store for spares and of a central repair shop was recognised by Lord Inverforth when he became Surveyor-General of Supply in May 1917, but for various reasons work was delayed and the depôt was only partly finished in November 1918. The possibility of utilising other national factories instead of continuing the work at Slough was then considered. Lord Inverforth, however, believed that large repair shops would be necessary to carry out the Disposal Board's decision that mechanical transport vehicles should be repaired before being disposed of, and that the shops would be a paying proposition if used in this way. He also believed that the depôt would be essential in the event of the setting up of a Ministry of Supply, one of whose duties would be the provision and maintenance of mechanical transport for all Government Departments, whose

[1] D.B./Sec/115. [2] Sec/Gen/827.

combined demands would probably be large. The scheme was therefore proceeded with on a reduced scale. The depôt was handed over by the War Department to the Ministry of Munitions in May 1919,[1] and during the summer and autumn of 1919 a large amount of repair work was carried out there, adding greatly to the value of the mechanical transport for disposal. In April 1920 the depôt, together with all the mechanical transport vehicles it contained and which might subsequently become the property of the Ministry, was sold to a syndicate headed by Sir Percival Perry.[2]

III. Restoration of Peace Industries.

The difficulties anticipated by firms in the restoration of their peace trade varied according to whether they had greatly altered their plant and the character of their output during the war, or merely continued their normal production on an increased scale. In the latter category were manufacturers of motor vehicles, machinery, scientific apparatus and chemicals, and the chief difficulty anticipated in such cases was to find an outlet for their surplus production, especially in view of the existence of large Government stocks of such articles. Thus, manufacturers of sulphuric acid and fertilisers anticipated serious over-production, since the potential output of sulphuric acid had increased very largely during the war, owing to the activities of the Ministry, and the probable future demand for fertilisers was unlikely to exceed the pre-war demand by much more than 20 per cent., while consumption in industry was quite small. The Board of Trade was anxious that compensation should be paid out of public funds to this trade for plant scrapped according to a definite scheme. The Treasury was, however, reluctant to embark on such a policy, since similar claims would almost certainly be put forward by other industries whose output had been specially stimulated for munitions purposes, and thought that the cost of reducing production, over and above allowances for exceptional depreciation, should be a charge on the industry.

The motor transport trade was also apprehensive of the effect of the enormous war production on its industry, and feared the results of throwing on the market a large number of second-hand vehicles. The Association of British Motor and Allied Manufacturers recommended that some arrangement should be made to prevent the importation and shipment from overseas theatres of American and foreign built vehicles for disposal in England. These fears proved to be groundless, for the time at all events, as there was a great post-war demand which arose on account of the revolution in inland transport brought about by the experience of the war, and there was a ready sale for all mechanical transport available for disposal.

The problem before those firms whose shops had been entirely reorganised for munitions production was that of reconverting the plant for peace purposes, a process absorbing considerable time and expenditure. In the case of the smaller engineering firms it was

[1] Sec/Gen/1102. [2] HIST. REC./R/1020/6.

occasionally found possible to use munitions plant with little alteration for peace purposes, *e.g.*, a manufacturer was able to make an immediate start on gramophones with plant installed for cartridge cases and fuses. Firms making aero-engine sparking plugs could develop commercial plugs and screw gauges, while makers of aeroplane components could turn over with little change of plant to motor car parts. The conditions in the large munition works were, however, quite different. It required at least nine months to reconvert a shop from the manufacture of aero-engines to that of motor cars, and the makers of aero-engines were in nearly all cases car manufacturers before the war.

The presence of Ministry-owned machinery in these works frequently complicated the change over to peace production. In many cases the machinery could be disposed of to much better advantage if would-be purchasers had an opportunity of seeing it in working order, but on the other hand the retention of plant in the shops actually interrupted the transit to peace organisation, and every effort was made, in spite of serious difficulties of transit and storage, to clear shops expeditiously when the contractors so desired. Many firms who had worked for the Ministry of Munitions were faced by the loss of their trade connections, especially abroad, as various Control Orders had prevented them from accepting orders from former customers. The position of these controlled firms was generally understood at home, but their inability to accept orders from abroad had led to the loss of markets, which had been captured by other countries. Moreover, such firms as had private orders on their books were often unwilling to carry them out, as they had been based on prices and wages below those current at the Armistice.

It will thus be seen that the industry of the country was involved in difficulties which required a great variety of treatment, and as, in many cases, the conditions were the result of Government action, a certain moral responsibility rested with the Ministry to assist its recovery.

There was some delay in relaxing priority control of manufacture and consequently, though by the beginning of December many materials had been freed from control, manufacture was still subject to priority regulation. There was some hesitation in suspending the Order, as, though the problems of the reconstruction period differed from those arising during the war, it was still necessary to ensure that urgent national and Allied reconstruction requirements had precedence in manufacture. The suspension of the Priority of Work Order except in special cases was discussed by the War Cabinet Demobilisation Committee early in December, but the reconstruction of the Government caused delay, and it was not until 1 February 1919 that firms were directed that priority should be given to work and materials in accordance with special directions only. On 1 March all priority certificates and permits ceased to be operative.

Certain trades were products of the war period, having been established either to meet some novel requirement or to supply products for which Great Britain had hitherto relied on enemy or foreign sources. In many of these industries, demand ceased immediately on the

conclusion of hostilities, and as they were in many cases essential or "key" industries, exceptional treatment seemed desirable. The general policy of the Government, as formulated in March, 1919, was to foster such industries by restricting imports for a limited or transition period, after which time the whole situation could be reviewed.[1] An Imports and Exports Regulation Bill was introduced on 19 November 1919 giving power to the Board of Trade to prohibit importation of 15 specified classes of goods, comprising the production of those industries considered to be essential for the welfare of the country, but this Bill was withdrawn at the end of the year, and it was not until 1921 that an Act was finally passed for the protection of these industries. Under this Act—the Safeguarding of Industries Act, 1921—certain industries were protected by the imposition of import duties of one third *ad valorem*.

An instance of such an industry established purely for war purposes was the production of tungsten. Wolfram ore, from which tungsten is made, is largely produced within the British Empire, especially in Burma and Australia. Before the war, only a negligible quantity of tungsten was made in this country and the manufacturers of high speed steel relied entirely for supplies upon Germany, where the manufacture was carried on in association with large chemical undertakings. Attempts to establish the industry in this country were met by organised price cutting from Germany. During the war, works for the reduction of wolfram ore were set up, and at the Armistice eight or nine firms were engaged in the production of tungsten powder and ferro-tungsten. Arrangement had been made early in the war with the Governments of India, Australia and New Zealand that all ore produced within the Empire should be shipped to this country during the war and for six months afterwards, but after the Armistice the demand for tungsten practically ceased and it was thought advisable both in the interests of the Ministry and of the wolfram ore producers that the Ministry's obligation to purchase should be cancelled as from 31 May, and the producers compensated for any loss due to the cancellation.[2] Lord Balfour of Burleigh's Committee took the view that tungsten manufacturers were sufficiently strongly entrenched to withstand German competition after the war, provided subsidies were granted them to compensate them for their outlay on research.[3] The tungsten producers were compensated for loss of markets after the Armistice by the Minister taking over from them all balances of wolfram or tungsten products at the prices in force on 11 November 1918 in full settlement of any claims against the Ministry, and control was suspended in October 1919. The industry was recognised as a key industry under the Act of 1921, and imports were subject to a duty of one third *ad valorem*.[4]

Another illustration may be drawn from the aircraft industry, which hardly existed in this country prior to the war. To meet naval and military demands very large extensions were undertaken to the

[1] *Parliamentary Debates* (1919), *H. of C.* CXIII, 954.
[2] Sec/Gen/442.
[3] Cd. 9032 of 1918.
[4] *Safeguarding of Industries Act*, 1921.

works of comparatively small firms. Few of these firms had any civil trade prior to the war, with the exception of engine contractors, who were usually motor car manufacturers, and could not revert to this production under nine to twelve months. Sympathetic treatment seemed necessary and a large amount of the apparently unproductive expenditure sanctioned by the Liquidation of Aircraft Committee in settling contracts was due to this policy. The transition period was exceptionally difficult for these firms. In March 1919 the Society of British Aircraft Contractors pleaded for special treatment with regard to excess profits duty. In many cases no pre-war basis of profits existed and a large part of the alleged profits had been put into plant and buildings to meet the war demand of the Government. The Society, therefore, asked to be allowed to retain a portion of the tax for a period as a loan at interest. The Liquidation Committee recommended some such arrangement, but as the Inland Revenue Department had no power to grant special concessions in respect of excess profits tax, it was suggested that the Air Ministry or Department of Aircraft Production should be empowered to make loans on satisfactory security to deserving firms of good financial standing to enable them to pay the tax.[1] Alternatively, it was suggested that some extension of time might be granted for payment of excess profits duty and relief was afforded in this way in certain cases, and also by extending the time for the repayment of Ministry loans.[2] The general policy of allowing an extension of time for repayment was not adopted until December 1921.

Both the scientific instrument and chemical and laboratory glassware trades were regarded as key industries, which, according to the report of Lord Balfour of Burleigh's Committee, "should be maintained in the country at all hazards and at any expense." Prior to the war the country was virtually dependent on Germany for the essential articles produced by these trades. After the outbreak of war it was necessary practically to create these industries from the foundation.[3]

The higher grades of the glass industry require specially skilled operatives and a direction, not only commercial, but possessing considerable scientific attainments. They carry meagre possibilities in direct profits, but are of vital national importance both on naval and military grounds and for all purposes of applied science and scientific research.[4] After the Armistice, the position of these trades was precarious, since no preparations as regards design and tools had been made for normal industrial production, while the manufacturers lacked capital to reconstruct their businesses for ordinary peace trade. Many of the war-time extensions had been financed by means of loans which were still outstanding. The rate of production was greatly in excess of the country's peace-time demand even under the most favourable conditions, and no foreign markets for British wares of this nature existed. Lord Balfour's Committee was satisfied that the continuance of commercial and scientific assistance and of detailed control on the

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[1] Sec/Gen/1028.
[2] Sec/Gen/1028.
[3] See Vol. XI, Part III.
[4] Cd. 9032 of 1918.

lines already followed during the war, would be necessary for a considerable period, and special measures of protection against foreign competition would be required at the outset in view of the great strength and reputation of German firms.

The Ministry's view was that the Board of Trade should be pressed to agree to the continuance of existing restrictions on imports of scientific instruments and glassware products.[1] In March 1919 it was agreed that the control of the industries should be handed over to the Board of Trade, while the supply side should remain with the Ministry. The question of financing the trade thus passed to the Board of Trade, but sufficient orders to carry the industry over the transition period were placed by the Ministry. Under the Safeguarding of Industries Act, 1921, optical and laboratory glass and scientific instruments of foreign origin were subject to an import duty of one third *ad valorem*.

In order to assist engineering firms in changing over to peace production, the Ministry tried, with the assistance of the Board of Trade, to obtain from other Departments and local authorities contracts for work which had been delayed by the war. Enquiries made by the Ministry during the war as to requirements of steel for such work had not elicited much information, and the result of a census of the available orders on 13 November was not encouraging, as it indicated that there were no orders in sight for a substantial proportion of the capacity. To overcome the reluctance of authorities to place orders when prices were at such a high level, it was suggested that the Government might help by bearing the difference in the cost of placing orders at once and a year later, or by relaxing the embargo on borrowing by local authorities, or assuming a more lenient attitude to the issue of additional capital by commercial firms. Several alternative methods of assisting in the solution of the problem were open to the Ministry of Munitions. The Department might either undertake the actual placing of orders, or might supervise and approve the placing of orders by other bodies, whether public or commercial, or might assist the trade by advances at interest to place immediate orders in anticipation of future demand. The onus for allocating orders seemed in any case to rest with the Ministry, which alone knew the actual conditions in the various trades. It was therefore agreed that the Board of Trade should accept responsibility for collecting orders, which the Ministry should distribute according to the needs of the industrial situation, acting throughout as agents for the Board of Trade. It was recognised that placing orders to meet hypothetical demands might subsequently involve the Government in difficulty in disposing of the articles, and the Demobilisation Board viewed with more favour any plan, such as financing trade associations, which would relieve the Ministry of the burden of accepting delivery and undertaking distribution, especially as wholesale purchases by the Department were not covered by the Vote of Credit and would require Parliamentary sanction. Of these alternatives the Treasury preferred the policy of direct orders or purchase by the Ministry. There was no actual proof that the need for financial

[1] (Printed) *Weekly Report* No. 177, I. (25/1/19).

assistance was holding back orders, as no applications for such assistance had been received, and the Treasury took the view that to offer it unasked would operate mainly in favour of weak firms who could not get ordinary banking accommodation. The necessity under the special circumstances of the time of incurring expenditure not strictly covered by the Vote was recognised, but the Treasury requested that all liabilities incurred with regard to orders placed with the trade should be put forward to them for sanction through the Munitions Expenditure Standing Committee.

Mr. Churchill's policy was to limit such orders as much as possible, and no separate department was set up to deal with them. They went in the normal way through the Requirements Branch to supply officers, and allocation was carefully watched to prevent favouritism. Towards the end of November, instructions were sent to a number of steel works giving definite orders for steel ingots. Small orders were also placed with copper smelters for the manufacture of material in such forms as were likely to be required in the near future. These firms experienced great difficulty in securing ordinary peace orders, owing to the high price of copper, and they held large quantities of material which the Ministry was under an obligation to buy at current market rates. The orders placed with them, therefore, helped to facilitate the liquidation of contracts as well as to relieve the immediate labour situation. The Ministry did not take this material into stock, but it was sold by the manufacturers *pari passu* with their own stock.

The policy of placing speculative orders was only continued for a short time to tide over the most difficult period. Lord Inverforth recognised that such orders would leave the Government without an answer to the trade deputations who were pressing for the retention of national factories by the Government. Thus, an adverse decision was made in the case of several firms who approached the Ministry with requests for orders for railway engines. The large demand for engines had led these firms to consider this production as a substitute for armaments, and they wished to obtain Government orders to establish confidence in them as engine manufacturers, but it was decided that no orders should be placed except against definite requirements from the Railway Executive.

CHAPTER VI.

SOME RESULTS OF CONTROL.

I. Economies in Production and Consumption.

On the credit side of Ministry control stand certain obvious economies in production and consumption which, having been considered at length elsewhere, will be briefly referred to in this chapter. These economies resulted from the power of controlling manufacture vested in the Ministry by Regulation 8.A. of the Defence of the Realm Act.[1] The legal effect of this regulation, which enabled the Department to require a factory to carry on its work in a way that would make it as useful as possible for the production of raw material for munitions manufacture, has been considered in an earlier volume.[2] Its practical application to munitions and non-munitions industries, aided by the control of materials and the operation of the priority principle, resulted in an enormous increase in output, more efficient industries and great economies in production. Of these the chief were the adoption of improved processes which economised labour and material, the utilisation of scrap and waste, and compulsory economy of materials both in munitions and trade factories. The engineering industry, in particular, benefited greatly from control and from the spread of standardisation and specialisation. Moreover, central control made it possible to consider the most economical methods of employing the machining capacity of the country by concentrating firms on the work to which they were most suited. The necessity of this was admitted on all sides, but competition between the supply departments of the Ministry and between the Ministry and other Government Departments prevented much progress being made in practice until nearly the end of the war.

(*a*) Spread of Improved Processes.

Many new or improved processes were developed in the iron and steel industry by the efforts of the Ministry of Munitions. The erection of basic furnaces enabled the manufacturer to rely to a larger extent upon home ores, and the replacement of the Bessemer process by open hearth furnaces, both economised pig iron and enabled a larger proportion of scrap to be used. Processes were adopted at Sheffield for producing from British materials, tool steel hitherto only made from Swedish bar iron; there were great improvements in foundry practice which resulted in the production of more reliable malleable cast iron, while experiments on the standardisation of hematite pig iron were carried out. In order to meet new demands for aircraft and tanks, special alloy steels were manufactured, the testing in the case of these and

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[1] See Appendix II.

[2] See Vol. II, Part I, Chap. VII.

other new products being checked in University laboratories and by the Ministry's consulting metallurgists.[1] In order to obtain more satisfactory steel castings for the track links of tanks, the Department introduced heat treatment whereby the tensile strength was raised from 28 to 40 tons per square inch, thus, it was claimed, inaugurating a new era in steel production.[2] A great deal of progress in the stamping and casting processes was due to the efforts of the Aircraft Production Department. Large expenditure on machinery was saved by skilful die casting, by which it was possible to produce parts which needed practically no machining, and which could be guaranteed for density and durability and to very fine limits of size.[3]

Modern methods and machinery were introduced in the optical munitions industry; processes were standardised and the design of some instruments modified in order to simplify production, and as a result it became possible to manufacture a large number of instruments in England for the first time.[4] The production of optical glass, ninety per cent. of which formerly came from abroad, was developed in a remarkable way as a result of applied research, specialisation and standardisation. The Department helped both with money and in the re-designing of factories, and at the end of the war the output of optical glass was 60 times greater than the pre-war output. New mechanical processes were also introduced in the commercial glass-making industry, which had to be controlled by the Department in order to provide essential glassware such as scientific glassware, electric lamp bulbs, lamp chimneys, glass bottles and containers hitherto imported from abroad.[5] In the same way the adoption of processes for extruding instead of casting or drawing brass rod and copper tubing, rendered a great increase of output and saving of material possible.

Interesting developments also took place in the manufacture of cupro-nickel strip for small arms ammunition. When the Ministry began its work, knowledge of the manufacture was largely empirical and was disseminated among the workmen themselves, so that in the opinion of some firms three years training was necessary for cupro-nickel casting.[6] Various experiments were undertaken by Ministry officials to determine the correct casting and annealing temperatures, (a simple pyrometer for workmen's use being produced), while other experiments proved the possibility of using, by means of an electric furnace, at least 50 per cent. of scrap in the production of envelopes for small arms ammunition without the loss of malleability hitherto associated with the use of a large proportion of scrap. Technical knowledge of cartridge brass manufacture was much more widespread, but methods of manufacture were crude and unscientific, and the Ministry was able to improve workshop practice to a large extent, dealing with such matters as the design of furnaces, the efficiency of combustion, the qualities of fuel used, the use of fluxes, the correct casting and annealing temperatures, and the design of

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[1] Vol. VII, Part II, Chap. VI.
[2] Vol. XII, Part III, Chap. IV.
[3] Vol. XII, Part I, Chap. VII.
[4] For details, see Vol. XI, Part III, Chap. II.
[5] See Vol. XI, Part III, Chap. III.
[6] HIST. REC. /H/1850/1.

ingot moulds, and the correct methods of pouring in order to produce a sound ingot, the existing practice being much more unscientific than the practice in steel foundries. As in the case of cupro-nickel, the percentage of scrap used was raised to 50 per cent. after a series of experiments which proved that the high percentage was not attended by the risks which even firms of the highest reputation for technical knowledge contended would follow.

A considerable amount of research into the methods of metallurgical analysis was carried on in one of the metallurgical laboratories of Sheffield University, and in addition to the knowledge acquired for immediate purposes, very valuable information was placed at the disposal of the industry generally, *e.g.*, the use of improved annealing methods especially salt bath annealing, the use of mechanical devices in the production of sound ingots, the influence of nonmetallic impurities in copper-nickel and copper zinc alloys and the use of electric furnaces for refining scrap metals in the non-ferrous trades.[1]

Another promising process, which was being opened up at the end of the war, was that of building up worn mechanical parts by the electro-deposition of metals. Considerable progress in the use of this process had been made in the army repair workshops of the Royal Flying Corps and the Army Service Corps in France. It had been found possible to build up to their original dimensions steel parts which had worn to the extent of two or three thousandths of an inch, and to take them back into use instead of putting them on the scrap heap. The extension of this process to worn ordnance, aircraft parts and other stores, and its adoption as a means of rectifying parts of munitions rejected on inspection as being below the specified dimensions was discussed,[2] and an interdepartmental committee, known as the Electro-Metallurgical Committee was set up to direct further research into the process. Assistance was obtained from Sheffield University, and by October 1918 the best working conditions as to the electro-deposition of iron had been ascertained, and research on the deposition of cobalt and nickel was going forward.[3]

(*b*) Utilisation of Scrap and Waste.

The utilisation of scrap of all kinds and of other forms of waste, thus economising money, tonnage and labour, is a feature of the period of Ministry control. Some account has been given elsewhere of the arrangements for collecting spent ammunition and other salvage from the battlefields,[4] and of the recovery of ammunition components which could be used again, such as copper bands, brass nose bushes and cartridge cases. The last was a very valuable form of economy, as each cartridge case could be re-formed two or three times, thus saving a very large amount of brass. Shell fired at proof ranges were also recovered and the steel and components utilised.

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[1] For further details, see Hist. Rec./H/1850/1.

[2] Hist. Rec./H/1800/3; M.C./611;

[3] For details, see First Report of the Electro-Metallurgical Committee. (Hist. Rec./R/1800/52).

[4] See Vol. VII, Part V, Chap. III; M.C. 113.

During the course of the war a large amount of shell was rejected as defective, and was at first treated as scrap. Later on, in order to make use of shell which, though slightly defective was still serviceable, a scheme for accepting this shell at a reduced price, which included provisions to penalise careless manufacture, was adopted. Later still, in 1917 and 1918, the increased demand for shell with chemical fillings provided a means of using a very large amount of the shell rejected as unfit for filling with high explosive by converting it to chemical shell.[1]

The use of a larger proportion of steel scrap in steel manufacture during the war was the result of constant pressure from the Ministry of Munitions.[2] The average percentage of scrap to the whole charge was raised from under 15 per cent. to nearly 50 per cent., thus providing a means of utilising the vast accumulations of steel scrap in the form of shell turnings, and economising high grade pig iron, the ore for which represented one of the Department's most formidable transport problems. Once the industry became familiar with the use of a high percentage of scrap the demand for it grew rapidly; blast furnaces competed with steel furnaces for supply and the amount supplied to the former had to be limited to conserve it for steel making. In addition to light scrap of this class a large amount of heavy scrap, old boilers, obsolete plant, railway material and so on, was made use of, but supplies of the oxygen necessary for cutting up this scrap by the oxy-acetylene process were never really sufficient for this source of supply to be fully developed. By the introduction of a de-tinning process in the last year of the war, the Ministry recovered a considerable amount of steel, and the accumulation of large stocks of empty tins, tin packages and containers of all kinds, made the use of this process of great potential value. Radium paint was also recovered from unserviceable instruments, 95 per cent. of its value being thus economised. Strict control of brass and copper scrap was introduced, and factories had to account for the scrap produced from all metal supplied to them, and cupro-nickel and cartridge metal scrap were largely utilised in the place of new metal.[3]

The Department's power of issuing Orders regulating the processes of manufacture in munitions industries greatly extended the scope of possible economies and substitutions. The work of the Explosives Supply Department in this connection is specially noteworthy. By the installation of oil and tar scrubbing processes, the recovery of coal tar derivatives from gas works was widely extended, while coke oven undertakings were induced to instal recovery plant. Before the war only some 50 per cent. of the coke oven undertakings in the United Kingdom had special plant for the recovery of benzol; the only by-product in the other undertakings was ammonium sulphate, all the valuable hydro-carbons being wasted. By the end of 1916 the Department reported that out of 8,426 ovens in operation in the United Kingdom, only two batteries, totalling 60 ovens, were without recovery plant. By this means, large quantities of benzol and toluol which were urgently needed for the manufacture of explosives were retrieved;

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[1] Vol. X, Part III, Chap. III. [2] Vol. VII, Part II, Chap. V.
[3] See above, p. 88.

the industry was put on a scientific basis and the waste of wealth due to the neglect of the industry's possibilities was checked. The manufacture of the new explosives, ammonal and amatol, and the consequent large demand for ammonium nitrate, led to the utilisation of ammoniacal liquor which had previously been regarded as a waste product. This liquor was concentrated and used as a substitute for ammonium sulphate in the preparation of ammonium nitrate, the process of converting industrial sulphate into nitrate having proved unsatisfactory and the acid required for the manufacture of the sulphate being urgently needed in the production of finished explosives. There had up to this time been very little demand for the weak ammoniacal liquor produced by the distillation of coal and the producers had reduced the amount recovered as far as possible, and in Devon and Cornwall it was actually wasted into the sea. In June 1916 the Explosives Supply Department took over the organisation of supplies of concentrated liquor, and, after choosing suitable designs of plant, urged producers to instal these plants and change over from the production of sulphate to concentrated ammonia. The entire output of liquor was bought by the Department at the standard price of 11s. 6d. per unit percentage of ammonia, and the Department inspected the processes of manufacture in order to maintain a high efficiency in output. Firms equipped with concentration plant were in many cases able to deal with the dilute liquor produced by firms who had no such plant, and the monthly production of ammonia liquor which, when the scheme was introduced, was not quite 500 tons, was raised to about 10,000 tons per month.

In October 1917 the Minister under the Defence of the Realm Act, required from all producers of coal tar or coke oven by-products, particulars of their output, working costs, sales, stocks and purchases. The by-products concerned included particularly tar, carbolic crystals, benzol, toluol, ammoniacal liquor, and sulphate of ammonia.[1]

Until the end of 1915 the consumption of acids in explosive manufacture was extravagantly large ; a number of explosive factories were not provided with adequate plant for the reconcentration of spent acid, which they consequently wasted. During the winter of 1915 an economy campaign was undertaken by the Explosives Supply Department, and concentration plants were erected wherever possible, the policy adopted being to limit the supply of acid to explosive manufacturers who had not put up recovery plants. The necessity for economising acid was recognised in planning the National Explosive Factories, and in their administration particular emphasis was laid on this point, and on plant efficiency in saving raw material. The result of these economies both in trade and Government factories is illustrated by the fact that, while in December 1915 the average amount of sulphuric acid used at T.N.T. works (expressed as 100 per cent. acid) varied from five to six tons of acid per ton of T.N.T., for the three months ending June 1916 it was 4·36 tons, for the three months ending June 1917 2·23 tons, while for the three months ending June 1918 it had fallen to 1·96 tons. Though part of this saving was due to

[1] Vol. VII, Part IV.

increased efficiency in other directions, much was owing to the recovery and re-use of waste acid.[1] The Department also succeeded in enforcing economy in the use of acids throughout the industries that employed them. Nitre cake, a by-product of nitric acid production containing about 30 per cent. of sulphuric acid, was at that time being produced in large quantities, and, with the exception of the small quantities used in the manufacture of hydrochloric acid, no commercial use had been found for it. It was a waste product until, owing to the efforts of the Explosives Supply Department, it was utilised by manufacturers in grease recovery from wool suds and in sewage precipitation, and later, in souring and pickling operations in the metal trades, thus economising sulphuric acid. By May 1919 it was being used for industrial purposes at the rate of 225,000 tons per annum and at the end of that year at the rate of approximately 288,000 tons yearly.[2] In the same way the supervision of cordite factories resulted in a great saving of material, 23 instead of 33 tons of acetone being used for each ton of cordite.[3]

Another valuable economy was the recovery from blast furnace dust of potash, which before the war had come from German sources. Normally, blast furnace dust from the stoves and boiler flues contains potash in sufficient quantities to form a useful fertiliser, but experiments carried out in 1916 resulted in the discovery that by adding a small quantity of salt to the charge of the blast furnaces, the dust was obtained in the form of a fine powder, which might contain as much as 50 per cent. of chloride of potash. For the removal of this dust, specially designed gas-cleaning plant was necessary, but where such plant was installed the cleaned gas became available as a source of power.[4] Up to November 1918 blast furnace dust recovered by the new process was received from three firms only, but gas-cleaning plant had been completed and the process adopted at other works which would have become sources of raw material had the war continued.[5] Another source of potash dust from cement kilns, which had hitherto been wasted, was also utilised by the Department.

Blast furnace dust recovered by normal methods is, as mentioned above, a valuable fertiliser, and in order to avoid speculation and render the dust available to farmers at reasonable rates, a scheme of distribution was arranged in conjunction with the Food Production Department of the Board of Agriculture. Under the scheme, dust was delivered in standard grades at fixed prices depending on the potash content. During the period January to December 1918 28,853 tons of blast furnace dust were made available for farming purposes and during the same period the quantity treated for the extraction of potash content was 5,964 tons.[6]

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[1] Vol. VII, Part IV.

[2] Vol. VII, Part IV, Of this, 1/4 was used in grease recovery, 1/4 in bleaching and dyeing, 5/24 in metal pickling and cleaning, 5/24 in hydrochloric manufacture, 1/24 in mineral water manufacture, and 1/24 in miscellaneous trade processes.

[3] Vol. X, Part IV, p. 109.

[4] Vol. XI, Part III, Chap. IV.

[5] Vol. XI, Part III, Chap. IV.

[6] *Ibid.*

Another possible source of carbonate of potash—suint liquor, *i.e.*, liquor resulting from washing greasy wool—was experimented with by the Department. It was found, however, that the total quantity available from this source in England did not justify any scheme of centralised manufacture, though the work of individual firms resulted in a certain amount of production by this method.

(*c*) Compulsory Economies and Substitutions.

Great economies were secured by the Ministry as a result of limiting the use of the highest grade materials to munitions for which they were absolutely essential, and substituting lower grade material for other munitions and civil work. These changes could only be introduced with the consent of the Design and Inspection Departments, which finally permitted considerable relaxations of specification in order to promote supply. Some of the chief examples of this are the increase of the percentage of sulphur and phosphorus allowed in shell steel for land service, the reduction in the fineness of the zinc required for brass fuse manufacture, the change from alloy steel to carbon steel in certain parts of aircraft engines, the use of American nickel instead of refined Mond nickel, the modification of some of the inspection tests for constructional steel, steel wires, etc., the grading of T.N.T. in order to allow the acceptance of lower grade material for certain purposes at a reduced price. Propellers and spars for aircraft were built up of short lengths of wood in order to economise timber, and a built-up spar superior in every way to the solid spar was evolved. The Air Board also agreed to accept lower grade mica for magnetos. A large amount of copper was saved by adopting a lighter driving band for shell and by manufacturing driving bands from strips instead of tubes, while aluminium powder was eliminated from explosives and smoke mixtures.

Sometimes the shortage of a material was so severe that the substitution of another material was the only way of maintaining the supply of munitions.[1] The outstanding illustration of this is the substitution of the amatol explosives for pure T.N.T.; other examples are the introduction of alternative forms of propellant in order to save acetone, the substitution of brass and later of cast iron for aluminium in fuses, and of papier maché for aluminium in the tips of small arms ammunition, of cast iron for steel in bombs and chemical shells, of creosote for petroleum in oil-fired engines, of oxides of antimony for lead and zinc in paint, of steel for brass in the centre tubes of shrapnel, and of wicker baskets in lieu of wooden shell cases.

Occasionally, as in the case of aluminium, the result of substitution effected such economies that a surplus actually became available.[2] Some attempts at substitution or economy failed. Thus, no substitute was found for lead in shrapnel shell; and cast iron fuses, nose bushes and fuse sockets were not very successful. The Aircraft Department substituted cotton fabric for linen fabric to a certain extent in aeroplane

[1] See A.C. 8 and Hist. Rec./R/1800/15 for an account of some of these economies.

[2] Vol. VII, Part III, Chap. V.; M.C. 300, 302.

production in order to economise linen ; cotton canvas was also used for hangars instead of flax canvas, but it was not found to be very satisfactory.[1] Substitutes for potash salts were used wherever possible in the manufacture of alum, cements, soft soap and insecticides, while permanganate of soda replaced permanganate of potash in many industries.[2]

Special efforts were made to economise timber, a branch being set up in 1917 to concentrate the work hitherto distributed among various departments, and to control the National Box Factories and the saw-mills erected to deal with home-grown timber. When the supply of naturally seasoned wood was exhausted, kiln drying was adopted both for the walnut and mahogany used for rifle stocks and aeroplane propellers, and for spruce and other aeroplane wood, and was found to be most satisfactory.

In order to economise coal, the Ministry placed limitations on lighting and took power to limit the consumption of electrical energy to factories whose output was essential. The prohibition of pleasure fairs and the restriction of exhibitions saved transport, coal and light, and the labour that would have been spent in finishing goods for exhibition.[3] Railway stock was economised by pooling the wagons owned by the railway companies, by standardising loading, and by improving the routing of traffic.

II. Improvements in the Engineering Industry.

The engineering industry of Great Britain has a longer history than that of any country in the world, and its pre-war organisation had some of the inflexibility of age. It was marked by a rigid individualism. Trade secrets were jealously guarded ; new methods introduced by first-rate firms were long confined to firms of that class, and there was a great gulf between the standards of firms at the top and firms at the bottom. It would probably be true to say that no country in the world could show such a high level of workmanship or so much out-of-date machinery. Repetition work on a large scale was comparatively rare in England, and a well-equipped engineering firm produced an endless variety of articles, not always on a commercial scale. Labour-saving devices were frequently neglected and the industry placed more reliance upon skilled workers than upon automatic machinery.

There was a great advance during the war period. In the effort to secure supply the Ministry of Munitions had to supervise methods of production and lay-out of plant. It succeeded in securing the services of some of the ablest technical experts in the country and it could draw on the experience of the Ordnance Factories and the expert knowledge of the great armament firms, while later on the records of national factories working on an unprecedented scale became available. There is no doubt whatever, that the result of Ministry control was a general levelling up of standards of accomplishment in the engineering trade, more economical use of material and of labour, the increased

[1] Vol. XII, Part I, Chap. V. [2] Vol. XI., Part III., Chap. IV.
[3] P.M./Gen/948.

adoption of labour-saving and automatic machinery, more accurate costings, and a higher standard of accuracy, attained by the use of precision gauges on a scale hitherto unknown in England.

At the same time there was great progress in standardisation, the most notable illustrations perhaps being in the construction of the engineering parts required for aeroplane construction, where the multiplicity of sizes and designs of steel tubes, rivets, screws, etc., was reduced by standardisation, thus economising skilled labour and gauges, and making the use of automatic machinery possible. With the help of the Engineering Standards Committee, standardisation was extended to water and fuel systems, wireless, electrical parts, ball and roller bearings, magnetos, wheels and tyres, dopes and fabrics, aircraft steel, copper alloys and so on. For example, when the Department began its work there were more than 650 sizes of copper tubing on order, but it was found possible to standardise one gauge in twenty-five sizes and to prohibit the use of other sizes.[1] Field and trench telephones were also standardised.[2] Machine tools were standardised to a large extent, and firms were forbidden to order special lathes to be built to their own specification, thus bringing the industry much nearer the condition of the American industry, which manufactured machines in bulk, not individual machines to special order. The number of screws and screw threads in use was reduced, thus economising both in production and in the use of screw gauges. The locomotive and railway wagon industry offered a great field for specialisation, as all the railway companies operated different types, and some progress was made in this direction and more in the introduction of standardised loading and handling appliances at ports and at factories.

The Department also succeeded in inducing engineering firms to specialise much more on certain types of work. Firms were dissipating their energies on the production of too many types of munitions, and not turning out an economical quantity of any particular store. The Austin Motor Company, for instance, was making shells, lighting sets, two types of aeroplane engines, X-ray apparatus, switchboards, lorries, armoured cars and gun parts. Specialisation diminished the number of jigs, gauges, tools and dies required, which were the product of the scarcest kind of labour, and rendered mass production and thorough dilution possible. The reduction in the number of types of radiators, for instance, manufactured by each firm resulted in a doubling of output in ten weeks without any increase in labour or plant.[3] Locomotive makers and railway wagon builders were taken off shell work and returned to their normal trade, a great improvement in output resulting.[4]

III. Efforts to Economise Machining Capacity.

Although the Ministry of Munitions succeeded in stimulating the engineering industry to unprecedented efforts, it was not entirely successful in making the best use of the new capacity it had created,

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[1] Vol. XII, Part I, Chap. IV, VII. [2] CRV/Gen/2123.
[3] Vol. XII, Part I, Chap. IV.
[4] HIST. REC./R/1000/8; D.M.R.S/434; C.R.V/Gen/875.

and the difficulties caused by the competition of the supply departments of the Ministry for manufacturing capacity were not solved during the life of the Ministry, though the creation of a Department of Engineering went some way towards a solution.

Firms played off one section of the Ministry against another, securing thereby more lucrative contracts and better conditions as to the supply of materials. Supply sections which came late into the struggle and which, with less experience, had not been able to reduce their contract prices by comparative costings, became much more popular with manufacturers than older departments, which had learnt how to place contracts on an economical basis. There was, therefore, a constantly increasing tendency for contractors to try and transfer their services to the newer department and the more remunerative work, which entailed delay and waste in conversion of plant.[1]

Again, the fact that the various supply departments had separate representatives led to a considerable waste of staff. Manufacturers were irritated by visits from half-a-dozen representatives of the Ministry on the same day, and by being asked to fill up many separate forms giving similar information, which the departments tabulated and compiled without communicating results to each other.[2] Half-a-dozen different branches of the Ministry were collecting statistics, and the result was confusion and waste of time and staff.

A memorandum on competitive buying forwarded by the Associated Chambers of Commerce to the Minister (14 November 1917) focussed outside criticism of the Ministry's unbusinesslike policy, and of the ruinous competition between supply departments. It drew attention to the fact that each department had a free lance staff, who were constantly interviewing contractors and offering strong inducements to them to change their work, which meant a loss of the efficiency and experience gained on the older contracts, especially those for shells and fuses, on which there had been a continual reduction in price. Shell and fuse contractors were being offered work by the Trench Warfare Supply Department, by the Aeronautical Supplies Department, and by the Admiralty, and there was not only competition but rivalry.

This indictment may be illustrated by the experience of the Small Arms Ammunition Department which found its contractors for brass castings making every excuse to reduce their output—their men were ill, had been called up for service, their plant had broken down and so on,—though at the same time they were actually increasing their output of brass rod castings for a section whose director was "kindlier," the explanation being that the Small Arms Ammunition Department paid a standardised price of £6 per ton with a two per cent. allowance for waste, while in the second case the manufacturers could get anything up to £15 per ton with a 15 per cent. allowance for waste.

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[1] Report by E.M. 7 to Organisation Committee, 7 May 1917.

[2] The Coventry Board of Management complained that the Area Office asked for statistics of output for a week ending on Thursday, while the Gun Ammunition Department asked for similar statistics for weeks ending on Saturday. (Hist. Rec/H/1121.24/2).

Anomalies of this kind were, of course, swept away as soon as discovered, but it was not easy to avoid similar if less striking difficulties arising from the competition between departments. The suggestion that one section of the Ministry should be responsible for all negotiations with the whole of any one trade, though theoretically correct, was difficult to carry into practice, as in the case quoted above where certain brass makers supplied two or three departments of the Ministry.

Improvement was effected in three ways, by the establishment of an Engineering Department to allocate manufacturing capacity economically,[1] by submitting contracts to the costings department which criticised them by comparison with a theoretical costing for work of the kind, and by adopting a more uniform policy of calculating allowances for waste and arranging for the disposal of scrap.[2]

The accumulation of standard costings was of great value. Other things being equal, higher costs usually meant that labour was being wastefully or inefficiently employed, or that management was defective in some other way; they indicated in any case the desirability of reducing the contracts given to the firm concerned. Where standardised products like shells, fuses or bombs were being manufactured it became possible to eliminate unsatisfactory firms by degrees, and changes in programme were taken advantage of for this purpose. But it was not easy to translate theory into practice. The demands of the Ministry were always outrunning the engineering capacity of the country and, as has been seen, firms who had ceased to obtain contracts from one department frequently obtained more remunerative contracts from another. Again, even when the reduction of the munitions programme in 1918 afforded a real opportunity of carrying this policy into effect by keeping only the most efficient contractors at work, the Minister felt bound to take other factors into consideration. The reduced programme would throw about 100,000 persons, chiefly women, out of work, and in view of the labour problem involved the Minister had to waive efficiency arguments, and adopt the policy of reducing contracts in congested districts, and in districts where alternative employment was available.[3] The Treasury declined to give a general sanction to the adoption of this policy, and the question lost much of its importance owing to the fact that the munitions programme did not have to be reduced as much as had been anticipated.

An interesting point was, however, raised by the Flax Control Board, which had adopted the policy of paying compensation to flax workers who were put on short time pledging the Government to pay half of the cost, a policy which the Ministry of Munitions refused to endorse without a Treasury ruling. The general question of policy was remitted to an Interdepartmental Committee and then to a Cabinet Committee, but by this time the end of the War was in sight and the question had lost its practical importance.[4] It is an interesting illustration, however of the complexity of the factors that had to be considered and the difficulty even under State control of translating economic precepts into practice.

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[1] See Vol. VIII, Part IV for a full account of this.
[2] See above, p. 89. [3] M.C. 618 [4] M.C. 618.

IV. Some Criticisms of Departmental Control.

As has been seen, hostility to State control was a national characteristic, and though the necessity of some measure of control was generally admitted, each manifestation of it aroused criticism from interested sections. As a rough generalisation, the general public welcomed control, manufacturers accepted it reluctantly, and middlemen were hostile. The general public realised that control saved them from extravagant prices, maintained supplies and distributed them as fairly as possible, while checking speculation and profiteering. Labour strongly supported State control and rationing, and indeed pressed for extensions of it.[1] Nearly all manufacturers objected to the supervision and interference that Government control involved, and the better organised firms questioned the value of departmental aid in obtaining materials, in technical questions and so on, though this help was appreciated by new, small or inexperienced firms. The majority of manufacturers, however, welcomed departmental help in labour questions, and firms rarely opposed becoming controlled establishments. On the other hand merchants were strongly opposed to control. They argued that if the laws of Supply and Demand had been allowed to operate unchecked, supply would have been stimulated in the ordinary way by high prices, and scarcity of essential commodities would have been avoided.[2] On these lines it was contended that the fixing of maximum prices by the Ministry of Munitions checked the flow of materials to the United Kingdom and diverted it to free markets, but this argument was countered by the assertion that the prices fixed by the Ministry were, (with comparatively small exceptions where the British Empire monopolised the sources of supply) calculated on the basis of the world's prices, and since competition from the Allies was diminished to a considerable extent by mutual arrangement, and enemy demand was eliminated by the blockade, the total effective competing demand was limited to neutral countries. It could, therefore, fairly be claimed that these arrangements for centralised buying, which would have been impossible without State control, counteracted any effect the fixing of prices may have had in the direction of limiting supply. This particular aspect of the question may be illustrated from the history of the control of non-ferrous metals. The very high prices which ruled when control was undertaken proved to be due to speculation and competition rather than real shortage, and after control and combined Allied purchasing came into force, larger supplies were forthcoming at much lower prices.

The operation of the system of export licences in particular was strongly criticised. Besides the delays incidental to a system which sometimes required diplomatic negotiations as well as a great deal of interdepartmental correspondence and consultation, merchants complained that trade was unnecessarily restricted, and that in some cases

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[1] The attitude of Labour to the policy of the Government with regard to the man power problem is considered in Volumes IV, V & VI.

[2] See Report of Merchants' Committee of London Chamber of Commerce, 12 July 1917. (HIST. REC./R/600/7).

the export of goods useless for war purposes, but valuable as a means of retaining trade connections, was banned. This view was strongly held by representative groups of merchants who urged that unnecessary hardship was being inflicted on the export trade, and that British traders were being deprived of a unique opportunity of capturing German markets.

The force of these arguments was admitted by the Ministry of Munitions and other Departments. They were well aware that the adverse balance of trade and the difficulty of financing overseas purchases of munitions and food made it imperative to stimulate export trade wherever possible, while the possible loss of British and Colonial markets[1] to Japan and the United States, and the failure to capture German markets in Holland and Italy, was not viewed with the equanimity that critics supposed. Nor was the effect upon German *morale* of developing British trade connections with former customers of Germany overlooked.

The effective prosecution of the war, however, had to rank first; it was extremely difficult to spare material, labour and coal from war industries for the manufacture of goods for export, and to divert shipping from war purposes for their transport when made, while another obstacle was the necessity of securing that the goods so exported did not ultimately find their way to Germany.[2] But there was room for doubt whether, in spite of all these drawbacks, more might not be done to help the export trade, and this was widely canvassed in the last year of the war. The Department of Overseas Trade in particular, while admitting the necesssity for restrictions, urged that there should be a greater elasticity in the embargo policy. It was recognised that embargoes on exports to Border neutrals were necessary from the blockade point of view,[3] and also from the political point of view, in order to put pressure on neutrals to grant the Allies facilities with regard to shipping, etc., but at the same time it was contended that it would be wiser policy to allow some deviation from the strictness of the embargo and conciliate neutral feeling by supplying certain articles of which they were much in need, even though there might be a great scarcity in Great Britain. Short as Germany was of raw materials she was exporting to Holland such articles as machinery, iron and steel and cement, and there were good reasons for imitating this policy of commercial propaganda, and maintaining a certain flow of exports, particularly to those foreign markets in which otherwise German influence might become predominant (as in the case of Holland), or might be regained, as in the case of Italy.[4] Such exports should be spread over as large a range of articles as possible, even though a small proportion only of the demand was supplied. Again it appeared desirable, in view of post-war trade, to supply undeveloped foreign countries with some part, at all events,

[1] The possibility of getting the Colonial authorities to impose import duties on articles of which the export from the United Kingdom was prohibited was considered. (Printed) *Weekly Report* No. 54 XI. (12/8/16).

[2] See above p. 26. Memorandum by Sir A. D. Steel Maitland, 29 June 1918.

[3] C.R.V./Gen/2379.

[4] See, for instance, the discussions about the export of high speed tool steel to Italy (C.R.V/I/067) and about German penetration in Spain (C.R.V/S/0436).

of the goods they formerly bought from the United Kingdom. Otherwise, of necessity, they would develop local industries, as was being done in Brazil and Chile, which would subsequently be protected by high tariffs. Sweden was another notable case of the development of home resources under blockade pressure.

Trade with India stood in a class by itself. It was generally agreed that export to India was specially desirable for financial reasons and to recover ground that was being lost by British trade, and it was possible to stimulate this trade without blockade and shipping difficulties being created. It appeared, however, that Indian and Colonial Priority Authorities were refusing to support applications for permission to import British goods which could be spared from the United Kingdom, and thus forcing applicants to supply themselves from foreign markets. The rigour of this practice was mitigated by instructions from the Ministry, in May 1918.[1]

But the Ministry of Munitions had to be very cautious in its acceptance of the general argument. Though the supply of materials was improving, few engineering firms had sufficient labour to enable them to undertake work outside their munitions contracts, and if commercial work were to be given a war grading, production for war purposes would have to suffer. The Ministry, however, was prepared to indicate which of the commodities specially required by customers abroad might be produced for export with the least interference with war supplies. This decision (17 July 1918) came too late to be of much practical value, but, as is seen above, the Priority Department of the Ministry had long before evolved machinery for keeping alive non-essential industries by allowing the necessary minimum of raw material, and had assisted in maintaining valuable trade connections by allowing priority for such schemes as the electrification of a Spanish railway, the equipment of a large waterworks at Cape Town, the supply of water tube boilers to Holland and Norway, and the construction of a big plant in Ireland.[2]

Another way in which State control threatened post-war commerce was by the diversion of trade from the normal channels and the concentration of buying and selling arrangements in the hands of Government Departments. It was obvious that direct interchange between Governments might be necessary in the case of materials required for war purposes, but it was urged that these and other exports should be carried out by arrangements assimilated as nearly as possible to the normal trade channels.[3] There is no doubt whatever that the policy of eliminating middlemen, though adopted for very good reasons, hit the merchant class very hard. They complained that the Ministry and other Government Departments underrated the services they rendered to British trade. Merchants engaged in the import trade contended that their expert knowledge of foreign markets, their foresight in buying in advance, and power of financing purchases would have

[1] C.R.V./C/579.
[2] See also C.R.V./R./070 (platinum mines in the Urals).
[3] C.R.V./Gen./2379.

maintained the trading stocks on which manufacturers depended, and that their policy contrasted favourably with departmental buying, which was slow and uninstructed and characterised by rigid financial methods which failed to maintain adequate trading stocks. In the same way export merchants contended that Government Departments not only acted unfairly but unwisely in attempting to eliminate the merchant from trades involving "an intimate knowledge of foreign markets, tariffs, languages, currency, exchange, fashions, etc., which no 'mere producer' possessed."[1]

Distributing merchants again had their grievance. They urged that when Government Departments had distributed available supplies through existing associations of merchants as in the case of wheat, flour, sugar, hemp and leather, they had been more successful than when, as in the case of the wool trade and the bulk of the metal trade, merchants were discouraged and supplies were distributed by the Departments.[2] It is clear that in certain trades those of the merchant class, who had previously performed useful services, had some ground for objecting to a policy which both deprived them of their livelihood and severed their valuable trade connections with their customers, but as a set-off this policy undoubtedly checked the rise of prices and protected legitimate trade by restraining the activities of speculators, brokers and commission hunters.

Trade generally was very hostile to the continuance of control and not disposed to give information about post-war requirements of materials. Thus, when the controlled establishments were circularised in February 1918 asking them to indicate their probable monthly demand for materials on the basis of their trading in time of peace, less than one fifth of the total number of controlled establishments sent in replies. A certain number of firms protested against the prospect of priority regulations being continued after the war, many were unable to give information owing to the shortage of staff, others regretted that "not being favoured with the gift of prophecy" they could not foresee requirements after the war.[3]

Perhaps the chief grievance—certainly the most constantly ventilated grievance—was the fact that State control meant the filling in of innumerable forms and returns which, according to pre-war British standards were unnecessarily intricate, minute and elaborate.[4] The trade in general doubted the value of the mass of statistical records required by the Ministry, viewed them as a device for harassing the trader by red tape entanglements and as a threat to trade secrets, and grudged the time and trouble they absorbed at a time of great pressure.

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[1] HIST. REC./R/600/7 Appendix III. The action of the Government in taking over the export trade in tin plates and black plates was specially condemned (*Ibid.*, p. 5).

[2] Certain non-ferrous metals and materials were distributed by the Ministry through existing trade agencies, or through associations of traders formed at the request of the Ministry, *e.g*, mica, platinum.

[3] HIST. REC./R./1830/33.

[4] Deputation from Central Council of Associations of Controlled Firms, 10 July, 1917 (HIST. REC./R/360/36).

Naturally enough, special hostility was aroused by the detailed examination of costs. Firms resented having to disclose information which might come into possession of their rivals, and resented still more the fact that the Ministry was frequently not content with the certificate of a chartered accountant, but sent down technical experts to enquire into the details of operations, to see if they ought to take as long, and if the costing was fairly apportioned between the operations. Many firms were anxious to have the allowances for establishment charges averaged, and objected to the discussion by Ministry experts of the establishment charges of individual firms. Another constant cause of complaint was the practice of leaving prices open until a job was nearly completed, and then fixing them on an examination of costs. The trade urged that this method should be confined to new stores, as it was most discouraging to the manufacturer, who had no incentive to produce cheaply.

In addition to these grievances, which were confined to controlled establishments, the whole industry of the country was subject to many inconvenient and irksome restrictions, had to familiarise itself with an elaborate procedure for obtaining licences and permits of all kinds, and with a bewildering number of Control Orders and regulations issued by various Government Departments, whose spheres of action had beeen determined by accident rather than principle.

The necessity of control was recognised by everyone but the complicated machinery it involved, some of the defects of which were undoubtedly due to the fact that the necessity for control had never been envisaged, was bitterly resented, and became the subject of much indignant eloquence. The debates on the Non-Ferrous Metals Bill reveal the depth of this hostility. Government control, it was said, paralysed industry. It inflicted the " maximum inconvenience on the public " and was viewed by the whole commercial community " with hatred and detestation," while the control exercised by the Ministry of Munitions was " vexatious and irritating and imposed by amateurs." The bureaucracy were " regular cormorants. . . . . insatiable and incompetent," whose one object was to try and retain after the war the powers granted them during the war. Special objection was taken to the proposal to examine traders' books. It was described as an inquisitional enquiry of a formidable character ; no Englishman felt he could trust the discretion of any public Department, and so on.[1]

While from one angle experience of State control stimulated an individualistic reaction against it, from another angle it was a powerful force in promoting commercial combines. By breaking down trade jealousies and secrecies and accustoming firms engaged in the same industry to joint action through a representative organisation, the Ministry encouraged the formation of trade combinations, involving great aggregations of capital and unions of producers formidable to consumers. During the war, while prices were controlled, this danger was a threat rather than a reality, and was set off by the general

[1] *Parliamentary Debates* (1918), *H. of L.*, XXVIII ; *Ibid.* (1917, 1918), *H. of C.* C, CI, *passim*.

improvement in manufacturing efficiency which resulted from better organisation and closer contact between firms engaged in the same industry. But with the passing of State control and the abolition of maximum prices the balance shifted, and the consumer had to face powerful trade combinations, in some cases originated, and in other cases educated and financed by the State.

During the war period State control had certain chances of success denied to it in normal times. Instead of being confined to the Civil Service, Government Departments succeeded in enlisting the services of some of the outstanding figures in the industries which they controlled. The obvious danger that interested persons might be swayed by interested motives was neutralised by the circumstances of the times. Self-interest was submerged in patriotism, and there is no evidence that these temporary recruits to the Civil Service made any attempt to profit by the exclusive information or privileged position they obtained in the service of the Ministry.

APPENDICES.

APPENDIX I.

(CHAPTER I, p. 2)

Schedule of Control Orders issued by the Ministry of Munitions.

Material.	Dates of Orders.	Defence of Realm Regulation	Nature of Control.	Department Responsible.
Acetone	8/12/16.	30A.	Dealings prohibited without licence.	Explosives Supply Department.
	20/12/18.	—	Control suspended.	
Acid, Acetic	21/9/17; 1/10/17	30A.	Dealings prohibited without licence.	Explosives Supply Department.
	20/12/18.	—	Control suspended.	
Acid, Sulphuric ..	29/5/17	2E., 15C.	Manufacture, use and sale prohibited without licence; maximum prices fixed; returns required.	Explosives Supply Department.
	10/5/18; 8/11/18	2E.	Prices revised..	Do. do
	30/5/19	—	Control suspended	
Aero-Engines	10/5/18	2E.	Experimental construction prohibited without licence.	Aircraft Production Department.
	20/12/18	—	Control suspended.	
Aeroplanes	30/3/17	2E.	Experimental construction prohibited without licence.	Aircraft Production Department.
	20/12/18	—	Control suspended.	
Agricultural Machinery	10/1/17	2E.	Manufacture or erection prohibited without licence.	Agricultural Machinery Department.
	21/6/18	2E., 15C.	Sale prohibited without licence; prices regulated; returns required.	Do. do.
	14/2/19	—	Control suspended.	
Aluminium	7/12/15; 21/7/16; 2/12/16.	30A.	Dealings prohibited without licence.	Non-Ferrous Materials Department.
	17/2/17	15C.	Returns required	Do. do.
	28/2/17	2E.	Use of scrap and swarf restricted; prices fixed.	Do. do.
	24/12/18	—	Control suspended.	
Ammonia	17/5/18	2E., 15C.	Manufacture and supply without licence restricted; returns required.	Explosives Supply Department.
	11/3/19	—	Control suspended.	
Ammonia, Sulphate of	30/4/18	2E., 15C.	Cost of distribution equalised; maximum prices fixed; conditions of sale regulated; returns required.	Food Production Department, Board of Agriculture.
	30/5/19	—	Control suspended.	
See also Coke Oven By-products.				
Antimony	29/2/16	30B.	Speculation prohibited ..	—
Ball Bearings	1/11/17	2E., 15C.	Manufacture and dealings prohibited without licence; returns required.	Machine Tool Department.
	7/1/19	—	Control suspended.	
Benzol	29/8/17	2E., 15C.	Supply of crude benzol prohibited without licence; returns required.	Explosives Supply Department.
	20/12/18	—	Control suspended.	
See also Coke-Oven By-Products.				
Binder Twine	15/2/18	15C.	Returns required	Agricultural Machinery Department.
Bismuth	12/3/18; 10/1/19	15C., 30A.	Dealings prohibited without licence; returns required.	Non-Ferrous Materials Department.
Blast Furnace Dust ..	7/8/17	2E., 15C.	Dealings and treatment prohibited without licence; returns required.	Potash Production Branch.
	8/2/18	—	Certain purchases for use as fertiliser permitted.	Do. do.
	15/4/19	—	Control suspended.	

APPENDIX I.—*Contd.*

Material.	Dates of Orders.	Defence of Realm Regulation.	Nature of Control.	Department Responsible.
Boilers	7/5/18	15C.	Returns required	Department of Engineering.
	10/10/18	30A.	Dealings in second-hand boilers restricted without licence.	Do. do.
	13/12/18	—	Control suspended.	
Brass	29/2/16	30B.	Speculation prohibited ..	—
	1/12/16	15C.	Returns required	Non-Ferrous Materials Department.
	24/2/17	2B.	Swarf and scrap taken possession of.	Do. do.
	17/12/18	—	Control suspended.	
Building Bricks ..	5/4/18	2E., 15C.	Dealings without licence restricted; returns required; delivery subjected to regulations.	Building Bricks Department.
	28/2/19	—	Control of dealings suspended.	
	18/3/19	—	Control completely suspended.	
Building Work ..	14/7/16	8E.	Work prohibited without licence, with certain exceptions.	Secretariat.
Calcium Carbide ..	24/9/17	2B., 15C., 30A.	Possession taken, dealings prohibited without licence; returns required.	Non-Ferrous Materials Department.
	7/3/19	—	Control suspended.	
Carbon	10/1/17	2E.	Dealings in gas works retort carbon prohibited without licence.	Raw Materials Department.
	19/4/18	2E.	Dealings in and use of gas works retort and coke-oven carbon prohibited without licence.	Do. do.
	18/4/19	—	Control suspended.	
Chlorine..	6/9/18	2E., 15C.	Manufacture, use and dealings without licence restricted; prices fixed; returns required.	Explosives Supply Department.
	20/12/18	—	Control suspended.	
Chrome Ore	31/8/17	30A.	Dealings prohibited without licence.	Non-Ferrous Materials Department.
	17/12/18	—	Control suspended.	
Coal Tar.—*See under* Tar.				
Cobalt	12/4/16	30C.	Unauthorised possession prohibited.	—
Coke, Metallurgical ..	7/7/16; 1/11/16; 27/11/17; 8/11/18.	30A.	Maximum prices fixed and revised.	Iron and Steel Department.
	29/4/19	—	Control suspended.	
Coke, Pitch	19/4/18	2E.	Dealings and use prohibited without licence.	Non-Ferrous Materials Department.
	18/4/19	—	Control suspended.	
Coke Oven By-products	31/10/16	15C.	Returns required	Explosives Supply Department.
	4/4/19	—	Control suspended.	
See also Ammonia, Benzol.				
Converter Plant, Electric	5/4/18	2E.	Dealings, manufacture, or installation without licence restricted.	Electric Power Supply Department.
	4/3/19	—	Control suspended.	
Copper	29/2/16	30B.	Speculation prohibited.	—
	5/6/16	30C.	Unauthorised possession prohibited.	—
	6/11/16; 8/12/16	2E.	Use, except for certified contracts prohibited.	Priority Branch.
	1/12/16	15C.	Returns required	Non-Ferrous Materials Department.
	8/12/16	30A.	Dealings in copper outside United Kingdom prohibited	Non-Ferrous Materials Department.
	1/1/17	2B.	Possession taken	Do. do.
	17/12/18	—	Control suspended.	

Appendix I.—*Contd.*

Material.	Dates of Orders.	Defence of Realm Regulation.	Nature of Control.	Department Responsible.
Copper Sulphate ..	15/2/18; 4/6/18	2E., 15C.	Returns required; maximum prices fixed and revised.	Explosives Supply Department.
	15/4/19	—	Control suspended.	
Cranes	20/12/16	15C., 30A.	Supply prohibited without licence; returns required.	Machine Tool Department.
	6/12/18	—	Control suspended.	
Creosote	13/7/17	2E., 15C.	Use for certain purposes and sale prohibited without licence; returns required.	Mineral Oil Production Department.
	15/1/19	—	Control suspended.	
. *See also* Oils, Tar.				
Cupro-Nickel Scrap ..	9/3/17	2E., 15C.	Use and sale prohibited without licence; returns required.	Non-Ferrous Materials Department.
	17/12/18	—	Control suspended.	
Electricity	8/11/18	11A.	New supply and use without licence restricted	Electric Power Supply Department.
	10/1/19	—	Control suspended.	
Eyes, Artificial Human	5/6/17	15C.	Returns required	Optical Munitions and Glassware Department.
See also under Glass.				
Ferro-Alloys	29/2/16	30B.	Speculation prohibited ..	—
	12/4/16	30C.	Unauthorised possession prohibited.	—
Fertilisers, Compound..	13/10/17; 14/11/17	15C., 30A.	Maximum prices fixed; conditions imposed on sale; returns required.	Explosives Supply Department.
	4/6/18	2E.	Manufacture prohibited without licence.	Do. do.
	30/5/19	—	Control suspended.	
See also Ammonia, Blast Furnace Dust, Potassium Compounds, Slag, Superphosphates.				
Flax	25/8/17; 8/2/18; 23/5/19.	2B., 30A.	Dealings prohibited without licence; possession taken.	Aeronautical Supplies Department; Flax Supplies Committee, Belfast.
	4/10/18	—	Control of dealings in flax outside United Kingdom suspended.	
	21/2/19	2F., 2JJ.	Charges fixed for scutching in Ireland.	Do. do.
	—/3/19	—	Control transferred to Board of Trade.	
Flax Seed	30/11/17	2B.	Possession taken of flax seed in United Kingdom.	Department of Agriculture and Technical Instruction for Ireland.
	14/12/17; 20/9/18	2E., 15C.	Sale and shipment from Ireland prohibited without licence; price regulated; returns required.	Do. do.
	18/6/18	2E.	Possession, use and dealings restricted.	Do. do.
	25/10/18	2B.	Possession taken of flax seed imported into Ireland.	Flax Supplies Committee, Belfast.
	23/5/19	—	Control of imported seed suspended.	
	21/10/19	—	Control completely suspended.	
Flax Straw—*see* Scutch Mills.				
Forgings, Ferrous ..	22/10/18	15C.	Returns required	Forgings and Castings Department.
Gas Works	28/6/18	8G.	Manufacture of gas subjected to certain regulations.	Explosives Supply Department.

APPENDIX I.—*Contd.*

Material.	Dates of Orders.	Defence of Realm Regulation	Nature of Control.	Department Responsible
Glass and Glassware ..	2/1/17; 23/3/17; 7/5/18.	2E., 15C.	Manufacture of chemical, medical and electric lamp glass prohibited without licence; returns required; dealings outside United Kingdom prohibited without licence.	Optical Munitions and Glassware Department.
	19/9/17; 7/5/18	2E.	Manufacture of glass and glassware (including artificial eyes and thermometers) subjected to regulations; dealings in electric lamp-glass in United Kingdom without licence restricted.	Do. do.
	31/7/19	—	Control suspended.	
Iron	29/2/16	30B.	Speculation prohibited ..	—
	7/7/16; 15/8/16; 1/11/16; 22/3/17; 17/7/17; 28/8/17; 30/11/17; 4/1/18; 1/2/18; 15/2/18; 20/8/18.	30A.	Maximum prices for various classes fixed and revised.	Iron and Steel Department.
	20/8/18	2E., 15C.	Scrap to be disposed of in accordance with requirements of Ministry; returns required.	Salvage and Stores Department.
	7/1/19	30A., 15C.	Quantity which may be purchased without licence restricted; returns of stocks required.	Iron and Steel Department.
	29/4/19	—	Control suspended.	
Ironstone	18/1/18	30A.	Maximum price fixed ..	Iron and Steel Department.
	29/4/19	—	Control suspended.	
Iron Ore Mines ..	24/7/17	9GG.	Possession taken	Iron and Steel Department.
	29/4/19	—	Control suspended.	
Lead	29/2/16	30B.	Speculation prohibited ..	—
	2/1/17; 6/4/17	2E., 15C.	Dealings and use without licence restricted; returns required.	Non-Ferrous Materials Department.
	6/4/17; 19/2/18 28/6/18.	2E.	Maximum prices fixed and revised.	Do. do.
	1/9/17	2B.	Possession taken	Do. do.
	28/5/18	15C.	Returns of type-metal required.	Do. do.
	17/12/18	—	Control suspended.	
Lenses, Photographic ..	19/1/17	15C.	Returns required	Optical Munitions and Glassware Department.
Lime, Acetate of ..	6/5/16	30A.	Dealings prohibited without licence.	Explosives Supply Department.
	20/12/18	—	Control suspended.	
Locomotive Engines ..	2/2/17	15C.	Returns required	Railway Materials Department.
Lorries and Trailers ..	26/6/17; 9/10/17	15C.	Returns required	Railway Materials Department.
	20/12/18	—	Control suspended.	
Machine Tools	28/8/16	30A.	Sale of power-driven metal-working machinery prohibited without licence.	Machine Tool Department.
	5/6/17	30A.	Dealings in power-driven wood-working machinery prohibited without licence.	Do. do.
	26/6/17	30A.	Purchase of power-driven metal-working machinery prohibited without licence.	Do. do.
	15/4/18	30A.	Dealings in treadle lathes prohibited without licence.	Do. do.
	11/11/18	—	Control of second-hand tools suspended.	
See also Small Tools.	23/5/19	—	Control completely suspended.	

APPENDIX I.—*Contd.*

Material.	Dates of Orders.	Defence of Realm Regulation.	Nature of Control.	Department Responsible.
Magnesite	9/1/17	2E.	Use for certain purposes prohibited without licence.	Iron and Steel Department.
	25/2/19	—	Control suspended.	
Mica	15/4/18	2E., 15C.	Dealings and use prohibited without licence; returns required.	Non-Ferrous Materials Department.
	30/5/19	—	Control suspended.	
Molybdenum	29/2/16	30B.	Speculation prohibited ..	—
	12/4/16	30C.	Unauthorised possession prohibited.	—
	30/11/17	15C., 30A.	Dealings prohibited without licence; returns required.	Non-Ferrous Materials Department.
	17/10/19	—	Control suspended.	
Motor Engines and Vehicles.	3/11/16; 6/1/17	2E.	Manufacture or erection of new motor engines, etc., prohibited without licence, with certain exceptions.	Munitions Inland Transport Department.
	6/12/18	—	Control suspended.	
Naphtha	29/8/17	30A., 15C.	Supply of crude naphtha prohibited without licence; returns required.	Explosives Supply Department.
	31/12/17	30A., 15C.	Dealings in crude solvent, solvent and heavy naphtha prohibited without licence; returns required.	Do. do.
	20/12/18	—	Control suspended.	
Nickel	29/2/16	30B.	Speculation prohibited ..	—
	12/4/16	30C.	Unauthorised possession prohibited.	—
Nitrate of Soda ..	18/10/17	30A.	Dealings prohibited without licence.	Explosives Supply Department.
	13/5/19	—	Control suspended.	
Oils and Fats ..	1/5/17	2E., 15C.	Dealings without licence restricted; prices fixed; returns required.	Explosives Supply Department.
	9/5/17; 19/6/17	2E.	Maximum prices revised ..	Do. do.
	18/3/19	—	Dealings permitted subject to price regulations being observed.	Do. do.
	29/4/19	—	Control completely suspended.	
Oils, Light	29/8/17	30A., 15C.	Supply prohibited without licence; returns required.	Explosives Supply Department.
Oils, Tar	23/10/17; 1/2/18	2B., 2E., 15C.	Possession taken; dealings and use prohibited without licence, except under certain conditions; prices fixed; returns required.	Mineral Oil Production Department.
	15/1/19	—	Control suspended.	
See also Benzol, Creosote, Naphtha.				
Oil, Whale	24/6/16	30A.	Dealings prohibited without licence.	Explosives Supply Department.
	1/5/17	—	Dealings in limited quantities permitted.	Do. do.
	31/1/19	—	Control suspended.	
Optical Munitions ..	23/11/15	30A.	Dealings prohibited without licence.	Optical Munitions and Glassware Department.
	31/7/19	—	Control suspended.	
Paper, Waste	15/5/17	2E., 15C.	Dealings prohibited without licence; returns required.	Royal Commission on Paper.
	14/3/19	—	Control suspended.	
Platinum	31/12/15; 31/5/16	30A.	Dealings prohibited without licence.	Non-Ferrous Materials Department.
	20/12/18	—	Control suspended.	

APPENDIX I.—*Contd.*

Material.	Dates of Orders.	Defence of Realm Regulation.	Nature of Control.	Department Responsible.
Potassium Compounds	17/10/17	15C., 30A.	Dealings prohibited without permit, except under certain conditions; returns required.	Potash Production Branch.
	7/12/17	—	Purchases for medicinal purposes permitted without licence.	Do. do.
	8/2/18		Certain purchases for use as fertiliser permitted.	Do. do.
	14/3/19	—	Control suspended except as regards kelp.	—
	31/7/19	—	Control completely suspended.	
Radio-Active Substances	13/8/18	15C., 30A.	Dealings prohibited without licence; returns required.	Optical Munitions and Glassware Department.
	21/1/19	—	Control suspended	
Railway Material, Second-hand	29/12/16	30A.	Dealings prohibited without licence.	Railway Materials Department.
	7/2/19	—	Control suspended except as regards wagons.	Do. do.
	14/3/19	—	Control completely suspended.	
See also Locomotive Engines, Steel.				
Refractory Materials ..	19/11/18	30A.	Maximum prices fixed ..	Iron and Steel Department.
	24/12/18	—	Control suspended.	
Rifles, Pistols, Revolvers, etc.	11/5/17	8A., 2E.	Manufacture and repair of sporting guns and rifles prohibited without licence.	Small Arms and Machine Gun Department.
	2/5/18	8A., 2E.	Manufacture and repair of all rifles, pistols, revolvers and shot guns prohibited without licence.	Do. do.
	15/11/18	—	Control suspended.	
Road Stone Quarries ..	9/5/17; 14/6/17	9G.G.	Possession taken	Road Stone Control Committee.
	7/8/17	—	Control suspended.	
Rosin	31/1/18	2E., 15C.	Dealings without licence restricted; returns required.	Non-Ferrous Materials Department.
	4/3/19	—	Control suspended.	
Rubber	25/10/18	15C.	Returns required	Mechanical Transport Department.
Scutch Mills	17/5/18	2E., 8A.	Scutching of flax straw in Ireland prohibited without licence.	Aircraft Production Department.
Seeds (including Oil Seeds, Nuts & Kernels)	1/5/17	2E., 15C.	Dealings prohibited without licence except under certain conditions; prices fixed; returns required.	Explosives Supply Department.
	9/5/17	—	Sale and purchase of special quality seeds for cultivation permitted.	Do. do.
	9/5/17; 19/6/17	2E.	Maximum prices revised ..	Do. do.
	18/3/19	—	Dealings permitted subject to maximum price not being exceeded.	Do. do.
	29/4/19	—	Control completely suspended.	
Shellac	12/3/18	2E., 15C.	Dealings without permit restricted; returns required.	Non-Ferrous Materials Department.
	10/12/18	—	Control suspended.	
Silk Waste	8/11/16	15C.	Returns required	Gun Ammunition Filling Department.
	14/1/19	—	Control suspended.	
Slag, Ground Basic ..	30/4/18	2E., 15C.	Cost of distribution equalised; maximum prices fixed; conditions of sale regulated; returns required.	Food Production Department, Board of Agriculture.
	30/5/19	—	Control suspended.	
Small Arms.—*See* Rifles.				

APPENDIX I.—*Contd.*

Material.	Dates of Orders.	Defence of Realm Regulation.	Nature of Control.	Department Responsible
Small Tools	10/5/18	2E.	Manufacture prohibited without licence.	Machine Tool Department.
	31/5/18	—	Manufacture for own use permitted.	Do. do.
	28/2/19	—	Control suspended.	
Spelter	23/3/17; 22/1/18	2E., 15C.	Dealings and use prohibited without licence; returns required.	Non-Ferrous Materials Department.
Steel	17/12/18	—	Control suspended.	
	29/2/16	30B.	Speculation prohibited ..	—
	12/4/16	30C.	Unauthorised possession of high-speed steel prohibited.	—
	7/7/16; 1/11/16; 1/1/17; 5/1/17; 22/3/17; 24/8/17; 28/8/17; 30/11/17; 4/1/18; 1/2/18; 15/2/18; 20/8/18; 8/11/18.	30A.	Maximum prices for various classes fixed and revised.	Iron and Steel Department.
	31/10/16	30A.	Dealings in certain classes prohibited without licence.	Do. do.
	20/11/16; 14/12/17; 24/12/17.	2E., 15C.	Manufacture prohibited except for approval purposes; priority of orders fixed; returns required.	Do. do.
	20/8/18	2E., 15C.	Scrap to be disposed of in accordance with requirements of Ministry; returns required.	Salvage and Stores Department.
	7/1/19	15C., 30A.	Quantity which might be purchased without licence prohibited; returns of stocks required.	Iron and Steel Department.
	1/4/19	—	Control of price of high-speed tool steel suspended.	—
	29/4/19	—	Control completely suspended.	
Superphosphates ..	20/8/17	15C., 30A.	Returns required; prices fixed.	Explosives Supply Department.
	17/11/17; 28/3/18; 30/4/18.	30A.	Prices revised	Do. do.
	30/4/18	2E.	Cost of distribution equalised; conditions of sale regulated.	Food Production Department, Board of Agriculture.
	30/5/19	—	Control suspended.	
Tap Cinder	15/12/17	30A.	Maximum prices fixed for tap cinder, mill cinder, flue cinder and scale.	Iron and Steel Department.
	29/4/19	—	Control suspended.	
Tar, Coal	31/10/16	15C.	Returns required	Explosives Supply Department.
	4/9/17	30A.	Dealings prohibited without licence, except under certain conditions.	Do. do.
	31/12/17	2E.	Use restricted	Do. do.
	20/12/18	—	Control suspended.	
Tar, Water Gas ..	31/12/17	2E.	Dealings and use prohibited without licence except under certain conditions.	Explosives Supply Department.
	20/12/18	—	Control suspended.	
Thermometers, Clinical	11/10/18	2E.	Sale prohibited of thermometers which had not been approved.	Optical Munitions and Glassware Department.
See also under Glass.				
Tin	5/6/16	30C.	Unauthorised possession prohibited.	—
	21/12/17	30B.	Speculation prohibited ..	—
	26/4/18	2E., 15C.	Dealings without licence and use except for certain contracts prohibited; returns required.	Non-Ferrous Materials Department.
	17/12/18	—	Control suspended.	

Appendix I.—*Contd.*

Material.	Dates of Orders.	Defence of Realm Regulation.	Nature of Control.	Department Responsible
Tow, Re-scutched ..	28/2/18; 25/10/18	2B.	Possession taken	Aircraft Production Department.
	25/10/18	15C.	Returns required	Do. do.
	26/9/19	—	Control suspended.	
Tungsten	29/2/16	30B.	Speculation prohibited ..	—
	12/4/16	30C.	Unauthorised possession prohibited.	—
	30/11/17	15C., 30A.	Dealings prohibited without licence; returns required.	Non-Ferrous Materials Department.
	17/10/19	—	Control suspended.	
Turpentine	25/1/18	2E.	Dealings without licence restricted.	Mineral Oil Production Department.
	18/3/19	—	Control suspended except as regards turpentine substitute.	Do. do.
	31/10/19	—	Control completely suspended.	
Vanadium	12/4/16	30C.	Unauthorised possession prohibited.	—
Yarn, Wet Spun ..	25/8/17	2E.	Use, manufacture and dealings prohibited without licence.	Aeronautical Supplies Department.
	4/10/18	—	Control suspended.	
Zinc	29/2/16	30B.	Speculation prohibited ..	—
	5/6/16	30C.	Unauthorised possession prohibited.	—

APPENDIX II.

(CHAPTER VI, p. 87.)

Defence of the Realm Regulation, 8A.

8A. It shall be lawful for the Admiralty or Army Council or the Minister of Munitions—

(*a*) to require any work in any factory or workshop to be done in accordance with the directions of the Admiralty or Army Council or the Minister of Munitions, given with the object of making the factory or workshop or the plant or labour therein as useful as possible for the production of war material, and to require returns as to the nature and amount of work done in any factory or workshop ;

(*b*) to regulate or restrict the carrying on of any work in any factory, workshop or other premises, or the engagement or employment of any workman, or all or any classes of workmen, therein, or to remove the plant therefrom, with a view to maintaining or increasing the production of munitions in other factories, workshops or premises, or to regulate and control the supply of metals and material that may be required for any articles for use in war ;

and the occupier and every officer and servant of the occupier of the factory, workshop, or premises, and any other person affected by any such directions, regulations, or restrictions, and where the occupier is a company, every director of the company, shall obey the directions, regulations, or restrictions of the Admiralty or Army Council or the Minister of Munitions so given, and if he fails to do so he shall be guilty of an offence against these regulations.

Where under this regulation any return has been required or any directions regulating the priority to be given to work at any factory, workshop, or other premises, have been given, and any person in any such return, or in any certificate or document given or issued for the purpose of securing priority for any work in pursuance of such directions, makes any false statement or false representation, he shall be guilty of an offence against these regulations.

APPENDIX III.

(CHAPTER IV, p 46).

Circular L. 33.

CONTROL OF OUTPUT.

GENTLEMEN,

I am directed by the Minister of Munitions to inform you that he deems it expedient, in the National interest, to take steps to ensure that the Productive Capacity of the Country on Munitions Work is regulated in such a manner as to ensure that such work has the proper order of priority in accordance with its importance.

The procedure described below has therefore been devised with a view to realising this object.

Classification.—To achieve this result, work must be classified in the order of its National importance. For this purpose three broad classifications, A, B and C, have been adopted, which are described in the Directions as to Priority attached hereto.

Certificates.—The management of any establishment to which Directions as to Priority have been given is required :—

(1) In executing an order placed with the establishment to give priority to the order according to the class to which the work ordered belongs.

(2) In placing an order for work with another firm or establishment to issue with every order and sub-contract a certificate as to the class to which the work belongs, if such work falls in Classes A or B.

Any orders placed or received without a certificate must be classified as Class C, and no work must be carried out on such order which would interfere with the progress of any order in Classes A or B. In the event of an order being received by your establishment without a certificate you should, in any case where you consider that priority for the work may be required, forward a certificate to the ordering firm or establishment, with the request that such certificate shall be duly completed and returned. With regard to work in progress, you are required to obtain from the ordering firm or establishment a certificate placing such work in the class to which it belongs, intimating that if no such certificate is received the work must be placed in Class C. Supplies of the form of Certificate may be obtained on application to Secretary, Ministry of Munitions, " C " Section, 6, Whitehall Gardens, S.W.

*Returns.**—A monthly return of the work completed in your establishment during the preceding month will need to be furnished in accordance with the Requirement as to Returns attached hereto, showing the amount of such work under the various classes. The actual form of return will be sent later.

I am to direct your attention to the fact that the making of a *false declaration on a Certificate or a false Return is an offence involving liability to heavy penalties under the Defence of the Realm Acts.*

The Minister confidently relies on your co-operation in the working of this procedure to ensure that the productive energies of the Country are concentrated on meeting the requirements of Munitions Works.

I am, Gentlemen,

Your obedient Servant,

H. LLEWELLYN SMITH.

DIRECTIONS AS TO PRIORITY.

The Minister of Munitions, in pursuance of Regulation 8a of the Defence of the Realm (Consolidation) Regulations, 1914, hereby gives the following directions to the owner or owners of the above establishment as to priority to be given to work in the establishment.

A.—Execution of Orders.

1. Priority shall be given to work at the above establishment in accordance with the classification set out in the First Schedule hereto.

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* This requirement was subsequently found by experience to be burdensome and was not enforced.

2. All work and orders for work or materials undertaken in the above establishment shall be divided into the three classes, Class A, Class B, and Class C, mentioned in the First Schedule.

3. Work and orders in Class A must take precedence of work and orders in Class B or Class C; work and orders in Class B must take precedence of work and orders in Class C, irrespective of the date when the orders were received, and of any contractual obligations to the contrary.

4. Subject to paragraph 6, orders for work received by the above establishment shall be treated as belonging to Class A* or Class B, if accompanied by a Certificate from the ordering firm in the form set out in the Second Schedule hereto stating that the work belongs to Class A or Class B respectively.

5. Any order for work received by the above establishment from any firm or establishment, and not accompanied by a Certificate in the form set out in the Second Schedule hereto to the effect that the work belongs to Class A or Class B, shall be treated as an order for work of Class C.

6. If there is reason to believe that any order for work received by the above establishment should be placed in a different class from that specified in the Certificate accompanying the order, application shall be made to the Ministry of Munitions, Priority Branch, Armament Buildings, Whitehall Place, London, S.W., for revision of the classification of the work.

7. Any particular or special instructions issued by the Ministry of Munitions as to the relative urgency of different work or orders belonging to the same class shall over-ride these general instructions. Application may be made by any firm or establishment where necessary to the Priority Branch for instructions as to the priority to be given to work or orders in Classes A or B, respectively.

B.—Placing of Orders.

8. Where any order for work is given by the above establishment to any other firm or establishment, it shall be accompanied by a Certificate in the form set out in the Second Schedule hereto stating the class to which the order belongs.

9. Where an order has been received by the above establishment certified to be of Class A or Class B, any order issued by the above establishment for any work or material required for the execution of the first mentioned order shall be certified as being of the same class as the first mentioned order.

10. If any doubt exists as to the class to which any order given by the above establishment is to be placed, reference shall be made to the Ministry of Munitions, Priority Branch, for directions.

Dated this 3rd day of March, 1916.

Signed on behalf of the Minister of Munitions,

H. LLEWELLYN SMITH.

First Schedule.

Classification of Work.

General Definition of Terms.

The term " Government War Contract " signifies :—

(1) Any contract placed by the Admiralty, the War Office, or the Ministry of Munitions.

(2) Any contract for naval or military equipment placed by an allied Government with the consent of the Admiralty, War Office, or Ministry of Munitions.

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* In the case of establishments, the priority of whose whole output is directly controlled by specific instructions from any Department of the Government, the establishment shall not treat any work or orders of Class A in reliance only on a Certificate given by another establishment, but must refer the question of so classifying the work or orders to the Department which controls its output, and must forward the Certificate. (This footnote was inserted with a view to excluding from the direct operation of this circular firms whose order book was under the direct supervision of a particular department, *e.g.*, the machine tool manufacturers, steel works, manufacturers of electrical generators, and various establishments controlled by the Director of Materials.)

The term " Certified War Work " signifies :—

(1) Work on a contract or order which the Admiralty, War Office, or the Ministry of Munitions has certified in writing to be War or Munitions Work.

(2) Work which the Ministry of Munitions has directed to be treated on an equality with War Work.

(3) Work on a contract or order which any firm or establishment has certified to be Class A work.

Definition of Class A.

Class A includes :—

Work or materials wholly required for :—

(*a*) A Government War Contract.

(*b*) Certified War Work.

(*c*) Merchant Shipping Work certified by the Board of Trade to be Munitions Work.

Definition of Class B.

Class B includes :—

Work or materials wholly required for :—

(*a*) Repairs to industrial machinery essential to maintain continuity of operation.

(*b*) Machinery necessary for the manipulation and transport of general freight.

(*c*) The production of such quantities of material, articles, or parts thereof as may be necessary to maintain reasonable stocks for the purpose of meeting the requirements for work of Class A or Class B.

(*d*) Work certified by the Admiralty, War Office, or the Ministry of Munitions as necessary for the efficient conduct of the War.

The following work may only be placed in Classes A or B, on the written authority of the Ministry of Munitions. In the absence of such authority, such work must be placed in Class C :—

(*a*) New locomotives, rolling stock, or other railway material.

(*b*) Motor vehicles, or repairs to same, other than those ordered by War Office, Admiralty, or Ministry of Munitions.

(*c*) New mining machinery.

(*d*) New textile, including hosiery and jute, machinery.

Class C.

Includes all work not included in Classes A or B.

Second Schedule.

[The Second Schedule contained a Form of Certificate and a Notice concerning Requirement of Returns under Regulation 8A.]

APPENDIX IV.

(CHAPTER IV, p. 44.)

Organisation of the Priority Department.[1]

The Priority Branch was formed in August 1915 in Deputy Director-General (B)'s division to deal with "priority and relative urgency." The sub-contractors section which already existed under Deputy Director-General (A) and had accumulated much information with regard to the distribution of sub-contracts was absorbed into the new branch, and in June 1916 the administration of Circular L.33 was taken over from the Controlled Establishments Division.[2]

The division of functions between the Priority Branch and the supply departments was defined in February 1916.[3] All departments were authorised to give instructions that contracts placed by the Admiralty, War Office, or Ministry of Munitions should be classed as "war work," and the Machine Tool and Raw Materials Departments might certify orders for tools, etc., to be war work where this was obviously the case. In all other cases the Priority Branch alone was authorised to certify work as "war work" or "necessary for the efficient conduct of the war," to authorise firms to proceed with non-war work and to give instructions as to relative urgency.[4]

The Priority Branch was assisted in the exercise of these functions by a Priority Committee, under the chairmanship of Mr. M. S. Amos (succeeded by Sir Charles Stewart-Wilson in September 1916). The Committee consisted of representatives of the different departments of the Ministry concerned, and later of other Government Departments, and met daily to consider the applications for priority submitted to the branch.[5]

As the number of applications increased, it became impossible to consider each one separately, and lists were prepared of (1) the most important cases, showing the decision suggested by the Priority Branch but open to challenge by any member of the Committee ("X" list), and (2) a few cases for detailed discussion, which on account of their novelty, complexity, or exceptional importance were left to the Committee for decision ("Y" list), and (3) trivial or common form decisions dealt with by the branch but recorded on the Committee's agenda ("Z" list).

The work of the Priority Branch was both voluminous and miscellaneous. The staff were mostly business men, who were seldom placed in charge of sections associated with the business in which they were particularly interested, as a reputation for disinterestedness was more important to the branch than any other qualification. Various sections and sub-sections were formed to deal with particular classes of permits,[6] and one section was occupied in taking up cases of irregularities and preparing cases for prosecution.[7] The work of the branch increased rapidly during 1916, and at the beginning of 1917, the question of priority organisation was considered by the Minister's Advisory Committee.[8]

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[1] For a detailed account see HIST. REC./H/620/6.

[2] See above, p. 46.

[3] Office Memorandum No. 43 (28/2/16); General Procedure Minute No. 17 (18/7/16).

[4] A department was not precluded from giving instructions as to the relative urgency of contracts placed by itself.

[5] See above, p. 45.

[6] For the organisation of the department at the time of the Armistice, see below, p. 121.

[7] Sub. 45462; (Printed) *Weekly Report*, No. 62, XI (7/10/16).

[8] A.C. 42.

As a result of this investigation, the Priority Branch became an independent department, under a Controller, and a Priority Advisory Committee, consisting of a few business men under the chairmanship of Mr. J. Wormald, was appointed to deal with the problem of private industries.[1]

As the Ministry grew in size and complexity of organisation the difficulties of the Priority Department increased. The number of applications multiplied rapidly, and, at the same time, representatives of many of the supply departments ceased to attend meetings of the Priority Committee. It was therefore suggested that a new committee should be formed, consisting of one representative of each group of departments under the Munitions Council, one representative of each Government Department interested in priority, and a commercial or city representative.[2] This scheme was not, however, carried out, and at the time of the Armistice, Co.onel Burgoyne, who had succeeded Sir Edgar Jones as Controller of Priority in July 1918 was developing a system of liaison officers to secure co-operation with other departments.

From the middle of 1917 the organisation of the Priority Department became mainly a question of inter-departmental priority. As has been shown above,[3] the department possessed no real authority outside the Ministry of Munitions, and as the war proceeded the need for a central authority became more apparent. In September 1917 therefore, a War Priorities Committee was appointed by the War Cabinet to co-ordinate the various demands made by Government Departments, and empowered to settle all questions of priority connected with munitions programmes.[4] The members of the Committee were as follows: General Smuts (Chairman), Sir Eric Geddes (Admiralty), Lord Derby (War Office), Mr. Winston Churchill (Ministry of Munitions), Lord Cowdray (Air Board), and Sir Auckland Geddes (Ministry of National Service).

In October, a Permanent Sub-Committee of the War Priorities Committee under the chairmanship of Sir Arthur Duckham (Ministry of Munitions)[5] was formed "to investigate in detail all recommendations by the Committee as to reduction of output or relaxation of effort in one direction and a corresponding advance and stimulus in another." It was subsequently arranged that the War Priorities Committee should confine its deliberations to questions of policy and principle, and that the Permanent Sub-Committee should consider questions of detail leading up to the formulation of policy.

The following committees were also appointed to deal with particular questions:—

(1) *Labour Dilution Committee* to go into labour dilution as a whole so far as the production of munitions was involved and to advise the Admiralty, War Office and Ministry of Munitions as to the further dilution possible.

(2) *Works Construction Committee* to prevent wasteful competition and to secure proper priority in regard to labour and material for the construction of new buildings.

(3) *Public Services Committee* to investigate the position as regards gas and electrical works, trams and railways, and other services of public utility, and to make recommendations as regards the priority essential in these cases.[6]

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[1] See above, p. 46.

[2] Hist. Rec./R/263.36/2; M.C. 289.

[3] See above, p. 45.

[4] M.C. 521.

[5] Hist. Rec./R/620/14.

[6] The Public Services Committee was re-formed at the end of 1917 as the General Services Committee, and its functions were extended to include the examination of labour and materials requirements of "uncalculated but essential needs not otherwise budgeted for, essential industries, and non-essential industries which it may be found necessary to keep alive in the interests of the trade of the country," and the presentation to the Allocation Committees of definite requirements. In January 1918 a sub-committee of the General Services Committee was formed under the name of Industries Committee (consisting of the members of the Priority Advisory Committee with representatives of the Board of Trade and the Priority Department) to deal with the question of civil industries. In June, this sub-committee replaced the General Services

At a later date, an Information Sub-Committee was formed to obtain returns of existing stocks of war material in the United Kingdom and abroad, the consumption thereof, and the normal stock which should be held. Other sub-committees were the Control Order Sub-Committee which was formed to prevent overlapping in the use of Control Orders (9 October, 1918) and the Electrical Services Sub-Committee, which was empowered to consider applications for the supply of electric light and power (14 October, 1918).

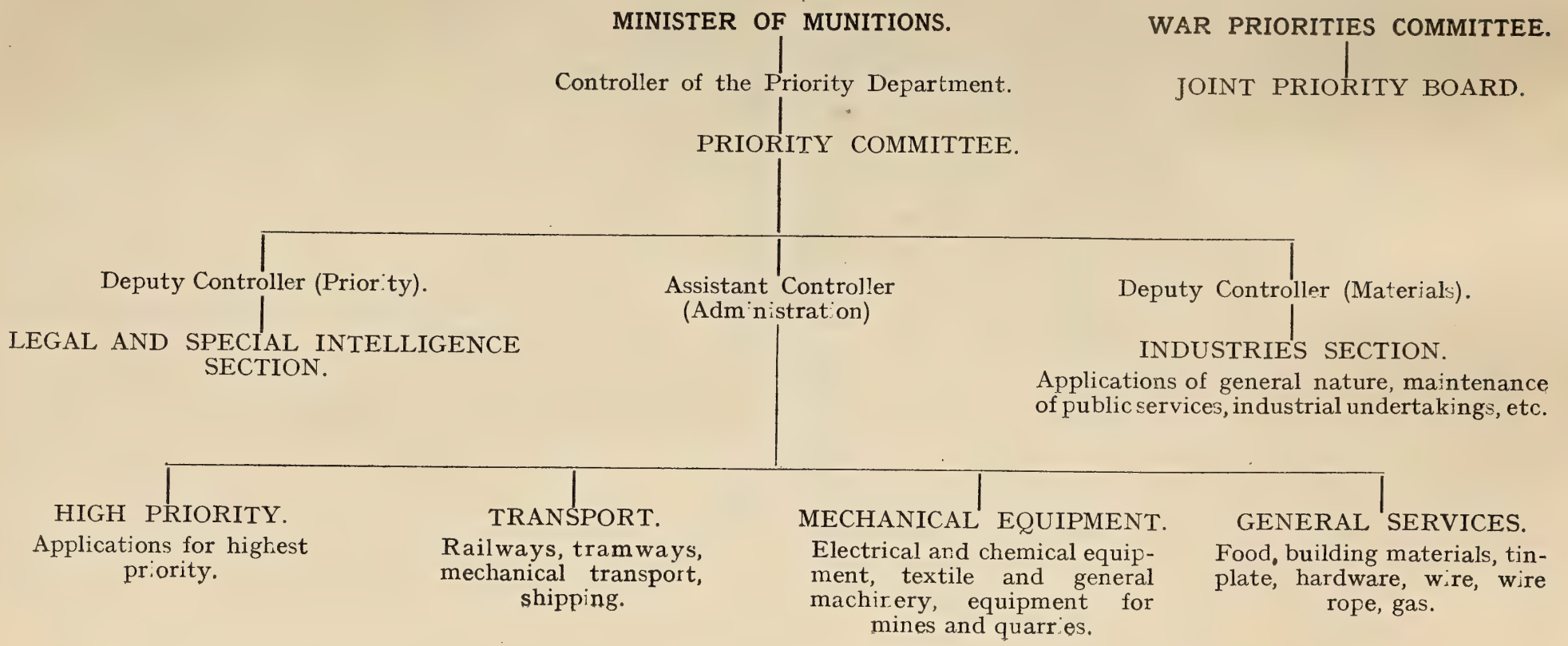
Allocation Committees were also established to bring together all the requirements of the various services and allocate bulk supplies to each, having regard to what was available for distribution. These committees dealt with steel, oxygen and calcium carbide, timber, linen and fabric, explosives and chemicals, non-ferrous metals and machine tools and ball-bearings.

The War Priorities Committee and its subsidary bodies secured an impartial allocation of various materials, but it touched the competition between departments for preferential treatment only indirectly. This problem so far as it affected the Ministry of Munitions was referred to a Council Committee (C.C. 35) at the end of 1917,[1] and as a result of the discussion which followed, the War Priorities Committee adopted a scheme for the establishment of a Joint Priority Board of the Admiralty, War Office, and Ministry of Munitions, with the Priority Department of the Ministry as its executive. The Joint Priority Board met for the first time on 18 October, 1918, with the Controller of the Priority Department as chairman, but the Armistice was signed before it had time to justify its existence.

Committee and a prolonged discussion arose as to its position and functions, which was only brought to an end by the Armistice and the dissolution of the Committee in January, 1919 (M.C. 758).

[1] M.C. 289, 754.

Organisation of the Priority Department, November, 1918.



SUPPLEMENT

THE DEPARTMENT OF THE SURVEYOR-GENERAL OF SUPPLY

SUPPLEMENT

THE DEPARTMENT OF THE SURVEYOR-GENERAL OF SUPPLY.

It has been thought desirable to add here an account of the Department of the Surveyor-General of Supply at the War Office, since it organised a system of commercial control analogous to that of the Ministry of Munitions and was later merged in the Ministry. As will be seen from the pages that follow, the system adopted was different in many respects from that of the Ministry, and some interesting comparisons, which could not be developed in the space allotted to the review of commercial control by the Ministry, are suggested by printing the accounts of both systems side by side.

I.—Formation of the Department of the Surveyor-General of Supply.

Even after the formation of the Ministry of Munitions in June 1915, the War Office was responsible for the supply of a variety of stores for the Army, such as food, clothing, equipment, medical stores, furniture, fuel, machinery, which were obtained through the Contracts Department and the supply branches under the Quartermaster-General and the Master-General of the Ordnance. The volume of stores required increased rapidly with the formation of the new armies, and the growing shortage of materials and man power rendered the task of supply increasingly difficult. In common with other Departments, the War Office found it necessary to assume control over materials which presented exceptional supply difficulties, and the success of the German submarine campaign in the early part of 1917 resulted in a rapid extension of this policy. It was therefore decided, in April 1917, to appoint a new member of the Army Council—the Surveyor-General of Supply—" to enable pace to be kept with the increasing volume and complexity of the commercial work of supplying the military forces,"[1] and to secure close co-operation between the Contracts Department and other supply branches. The Surveyor-General of Supply, Mr. Andrew Weir (later Lord Inverforth), took over from the departments of the Quartermaster-General, the Master-General of the Ordnance and the Finance Member all commercial duties relating to supply, and the different departments became responsible to him for the formulation of their demands. By this means, demands from all sources could be reviewed in the light of industrial and commercial conditions.

[1] *Parliamentary Debates* (1917), *H. of C.*, XCII, 2583.

It had already been the policy of the War Office in exercising industrial control to share with the industry concerned a large part of the responsibility for dealing with difficulties which required co-operation with trade and labour organisations. A number of business men, experts in their particular trades, had been placed upon the staff of the War Office, and the services of others had been secured to act on advisory committees. This policy was still further extended under the Surveyor-General of Supply. A number of supply committees were formed to examine and revise demands, to consider the amendment of patterns and specifications in order to facilitate supply, and to make suggestions for meeting probable future requirements. Each of these committees dealt with a particular class of supplies and consisted of representatives of the requisitioning and purchasing branches, under an independent chairman of commercial experience. A system of control boards and committees was set up to deal with the various control schemes. These boards kept in close touch with the industry concerned, and had under them administrators with business and technical qualifications. They were chiefly concerned with the administration of supplies of controlled raw materials and the industries dependent on them. An essential part of the organisation set up by the Surveyor-General of Supply was a committee composed mainly of business men which was constantly engaged in examining the possibility of making further economies in the expenditure on stores and supplies of all kinds. The committee was assisted by expert representatives of each Military Directorate as its work came under review, and included a member of the Finance Department.

II.—Administrative Organisation.

On passing to the Department of the Surveyor-General of Supply, the original War Office Contracts Directorate was divided, and its duties were distributed among new directorates instituted for specific purposes. The Director of Raw Materials was appointed in July to take over from the Director of Army Contracts the controls then administered by the War Department, *i.e.*, wool, leather, cotton, jute, flax and hemp, and the purchase of goods made therefrom, together with the organisation of the trades concerned, thus leaving with the Contracts Directorate of the new department, the provision of stores for the supply of which no special administrative control was necessary. The abnormal conditions of the wool textile trade called for special administrative measures. The control already exercised to secure Government supplies, made the provision of essential civilian needs increasingly difficult, and to cope with this problem and to provide for the increasing scale and variety of Government demands, the Directorate of Wool Textile Production was set up, to supervise under the Director of Raw Materials the production of cloth and hosiery, beginning its operations after the stage at which wool is converted into tops.

A Contracts Board was established under the chairmanship of the Assistant Surveyor-General of Supply to supervise the work of the Contracts and Raw Materials Directorates, and to deal with important

questions of policy with a view to securing better co-ordination between the military requisitioning branches and the purchasing branch. In peace time, the requirements of the Inspector of Iron Structures, under the Director of Fortifications and Works, were met through the Director of Army Contracts. On the outbbreak of war the Inspector's branch became responsible for providing and shipping all engineer stores required from England for the various Expeditionary Forces. In view of the urgency of the requirements, a wide purchasing authority had been delegated to the Director of Fortifications and Works, to be exercised through the Inspector (then known as the Chief Mechanical Engineer). As a consequence, a contracts section was developed, connexion with the Director of Army Contracts being maintained by the notification of contracts over £100 and by the reference for decision or advice of any question of principle. On the appointment of the Surveyor-General of Supply, the commercial functions of the Director of Fortifications and Works passed to his control. It then became possible to take up the question of competition between this contracts section and the Contracts Directorate, which purchased for home requirements many of the stores purchased by the Director of Fortifications and Works for the Expeditionary Forces. In January 1918, when arrangements were being made to supply the American Expeditionary Force, competition became more marked, and an arrangement was made whereby the Contracts Branch purchased all supplies of a general commercial description, while the Chief Mechanical Engineer bought special technical stores, and inspected not only these but also the engineering stores purchased by the Contracts Directorate. Similar arrangements were made in regard to the contracts section of the Inland Waterways and Docks Branch, whose purchases, like those of the Chief Mechanical Engineer, had been found to compete with those of the Contracts Directorate.

(*a*) CONTRACTS DIRECTORATE.

In general, the Contracts Department dealt with stores which were obtainable by ordinary methods, without interference by the department with the industries concerned. The directorate was organised in five sections dealing with :—(1) general stores, including hardware, cutlery, wire, tools, pottery, timber, woodware, brush and basketware, oils and chemicals ; (2) consumable supplies, including food, forage, coal and tobacco ; (3) building works and materials ; (4) made-up clothing (not including hosiery) ; (5) drugs and surgical supplies.

Early in the war local contract offices were established at Sheffield and Birmingham to deal respectively with contracts for cutlery and tools, and for tools, hardware and other Birmingham supplies. The original purpose of these offices was to assist contractors and hasten deliveries, but the scope of the work gradually extended. Technical experts were placed in charge and were often able to suggest improved means of production. Later, the local offices regulated the distribution of all raw and semi-finished materials among about 1,500 firms, and all proposed allocations of contracts in the districts covered by their activities were referred for their consideration and advice.

At the end of 1917, advisory committees of manufacturers in the various centres were invited to assist the department in stimulating the production of army clothing, with excellent results. Later, a central committee was nominated to confer with and advise the department in matters generally affecting the trade in the production of army requirements.

(*b*) DIRECTORATE OF RAW MATERIALS.

The three sections of this directorate dealt respectively with (1) the purchase and distribution of wool ; (2) the control of leather supplies and (3) the control of fibres. The responsibilities of the directorate included the importation and distribution of kips and tanning materials, the control of native hides, the production and distribution of leather, the control and purchase of leather goods, the importation and distribution of jute, hemp, flax and raffia and the purchase of goods manufactured from these materials and from cotton.

A Central Wool Advisory Committee comprising, besides members of the War Office, Board of Trade and War Trade Department, members of all sections of the trade and representatives of labour, was set up at the beginning of April, 1917, to devise methods of building up a reserve of wool. Later, the functions of this committee were divided. A Raw Wool Advisory Committee was constituted in August, 1917, under the chairmanship of the Director of Raw Materials to advise on all matters connected with the purchase and distribution of raw wool up to and including the top making stage, and with regard to manufacture ; a board of control was set up at Bradford, under the Director of Wool Textile Production, with certain executive powers, including the control of a priority scheme of distribution and matters dealing with the restriction of consumption.[1] A number of smaller committees to advise on questions affecting specific branches of the trade were also set up, such as the Top-making Advisory Committee, the Clothing Wool Committee, the Noils Merchants Committee, and the Carbonising Committee.

A departmental Leather Control Board was established in July, 1917, each member having under his charge some important section of the work. The department was also advised and assisted by a Central Leather Supplies Advisory Committee formed of employers, employees and representatives of the Departments interested in leather. Eighteen sub-committees were formed to advise on particular aspects of the trade, of which the members had special knowledge.

Certain changes were made in the method of purchasing cotton goods, owing to the great increase in requirements during 1918. The cotton industry was controlled by the Cotton Control Board of the Board of Trade, and, until the end of 1917, War Office supplies had been purchased by a business organisation on a commission basis. This agency failed to cope with the increasing demand and a War Department Cotton Textile Office was set up in Manchester to buy

[1] See below, p. 143.

cotton goods. By this means, the buying costs, already low, were further reduced, and prices were fixed for yarns used for Government textiles.

An important development under the Surveyor-General of Supply was the establishment of the Flax Control Board in October, 1917, to supervise and co-ordinate the arrangements made by various Departments for obtaining supplies of flax, flax seed, and flax goods for war purposes, and to secure that, as far as possible, after meeting requirements for aeroplanes, sufficient flax should be available for other war purposes. This Board was assisted by Scottish and Irish sub-committees.

(*c*) DIRECTORATE OF WOOL TEXTILE PRODUCTION.

The Directorate of Wool Textile Production dealt with the control of wool after the raw material stage, tops being regarded as the raw material of the worsted industry. During the first half of 1917, committees were set up representative of groups of manufacturers in every district and in every section of the trade to advise on and make arrangements for the allocation of contracts among individual manufacturers in their areas, the Department of the Surveyor-General allotting a bulk allocation to each committee. This method of sharing with the trade the responsibility for supply was afterwards extended to every branch of the wool textile industry and culminated in the establishment, as mentioned above, of a Board of Control of Wool Textile Industries to control civil trade. The Board consisted of 33 members, one-third of whom were representative of employers, one-third of labour and one-third of departmental officers, the majority of whom were prominent business men, previously engaged in the wool textile trade. The Director of Wool Textile Production was chairman of the Board, and the directorate was responsible for carrying out the Board's decisions.

(*d*) COSTINGS DIRECTORATE.

When, with the expansion of the Army, the industries of the country were beginning to feel the strain involved in the unprecedented production required, the War Office Contracts Directorate initiated the system of requiring contractors to justify their quotations by the submission of costings. This system, which was begun in June, 1915,[1] was gradually extended, and when the Department of the Surveyor-General of Supply was formed, the investigation of contractors' costs was being carried out by a staff of eight skilled investigators and five office assistants attached to the Directorate of Army Contracts. There were also two chartered accountants who had been lent to the department in an advisory capacity who, either directly, or with the assistance of local firms of accountants, investigated the costs of a large number of contractors throughout the country. In June, 1917, a single Costings Branch, under a Director of Costings, was established to co-ordinate these two sections, and extend the work to cover all contracts and operations in raw materials. Sub-sections were formed,

[1] *Memorandum on War Office Contracts* (Cd. 8447).

composed of three or more investigators who specialised in particular trades and dealt with them at the centre of the industry in each case. Besides being charged with the investigation of costs and claims submitted to it by the Directorates of Contracts, Raw Materials, or Wool Textile Production, the section examined on behalf of the Surveyor-General any contract which was considered by him to need investigation. From its records and past experience, the directorate was often able to advise on prices, without the necessity for visiting contractors' works.

In the wool textile industry, prices at each stage of production were determined on the basis of "conversion costs." The department owned the raw wool and issued it at fixed prices, either in the raw state for the woollen trade, or in the form of tops for the worsted trade. The process of blending the raw wool and mixing with it other fibres, such as pulled rags, wool waste, cotton, etc., is one requiring considerable skill and technical knowledge, and it was at this stage that the knowledge of the technical officers was essential to check cost and prevent waste of raw material. The cost and constitution of the blend having been fixed, the next stage was to ascertain the conversion costs, or cost of services rendered in converting the raw material into yarn and the yarn into cloth, these costs being based upon average surveys of a number of manufacturers' costings in the particular trade group or district concerned. These costs were determined by the technical officers of the directorate and the accountants responsible to the Director of Costings.

The introduction into the manufacturing processes of such materials as cotton and oils, whose prices fluctuated and supplies of which were uncontrolled, added greatly to the difficulties of determining costs. In many cases, it was necessary to fix rates tentatively, subject to later re-adjustment. The costings submitted by a manufacturer in connexion with a particular contract were scrutinised and approved by the department's technical officers before the contract was placed, in order to make sure that they conformed to the key costings for the section of the trade concerned. It was not found possible to lay down any definite rule to determine what was a reasonable margin of profit. Each case was considered by the directorate upon its merits, and the percentage to be allowed was arrived at with a due regard to the relation of the turnover to the capital employed and to the nature of the business and its pre-war earnings. In the case of continuous contracts, the percentages allowed both for overhead charges and for profit were revised and reduced as the cost of material and labour increased. The system was intended to fix prices for Government supplies at such a point as to provide a fair profit to manufacturers, irrespective of abnormal conditions, which, if left to operate in the ordinary way, would have led to exorbitant prices.

The system outlined above was adopted as the best which had been devised. It did not, however, in practice, secure that the margin of profit was as small as that allowed in peace time by the method of public tender, when orders went by competition to the firm which could produce at the lowest cost. The supply of skilled accountants was

insufficient for the investigation of costs at every factory, and it therefore became necessary to fix prices which would give a working profit to the less efficient firms and which resulted in large profits to really efficient manufacturers. It was also found difficult to estimate with accuracy the economies obtainable when producing standard goods in large quantities.

(*e*) ARMY PRIORITY DIRECTORATE.

Questions of priority became so complicated during 1917 that it was found necessary to establish a separate directorate under the Surveyor-General, to review all demands by the Allies, the general policy in regard to import and export licences and war trade, and all questions of priority affecting the department. The supply of goods to the Allies during 1918 was considerably affected by the extension of Government control over industry, the tendency being to increase the number of stores purchased for Allies by the War Department. The shortage of tonnage had a similar effect, as it often involved supply by this country of needs which would otherwise have been met by the United States. The entry of America into the war also increased demands on the manufacturing capacity of Great Britain, to supply the needs of the American Army. At the same time the increasing shortage in many vital supplies rendered essential a closer allocation of available stocks. The Directorate of Army Priority dealt with issues to Allies from War Office stores, and with purchases made on their behalf. The section dealing with issues to the Allies from stock (including munitions) was transferred from the Civil Member, and considerable advantages were found to be derived from its linking up with the priority work generally. Close liaison with the General Staff and the Treasury was established, and the organisation adopted facilitated rapid decisions, based on fuller information than had previously been available in this important sphere of supply work. Another important branch of the work of the directorate was the exercise of control by means of export and import licences. The Director advised the War Trade Department as to whether export should be allowed, and the Department of Import Restrictions (Board of Trade) as to the advisability of importing certain goods on the prohibited list. The directorate also dealt with demands for priority made on the department by its various contractors, and was responsible for adjusting the relative degrees of urgency in demands from various sections of the War Office. The directorate also distributed the department's allocation of steel and tin plate.

(*f*) SALVAGE.

In November, 1917, an Army Salvage Branch was formed. The existing arrangements for collecting and disposing of salvage both at home and in the theatres of war were felt to be inadequate, and it was believed that great economies could be effected by the institution of more comprehensive and effective machinery. The duties of salvage, repair and disposal were vested in a Controller of Salvage acting under the general direction of an Army Salvage Board. To co-ordinate the

work of the various Departments concerned in salvage, a National Salvage Council was formed at the instance of the Surveyor-General, consisting of representatives of the War Office, Admiralty, Ministry of Munitions, Ministry of Food, Board of Agriculture, Local Government Board, Board of Trade and Ministry of Reconstruction. The functions of this body and of the Executive Board and Director-General of National Salvage, who were appointed as part of its organisation, were to secure, in co-operation with existing authorities, the prevention of waste and the collection, recovery and re-utilisation of waste products with a view to conserving national resources.[1]

The Army Salvage Branch endeavoured, where possible, to supply the needs of one Service from material rejected by another, and to dispose to the best advantage of anything which was entirely useless for army purposes. The duty of organising the collection of salvage of all descriptions in the home areas was vested in a Deputy Assistant Quartermaster-General (Salvage). No special Salvage Corps was formed, but at each Command at home and in the theatres of war, specially selected officers were appointed for salvage work, to function departmentally under the Controller of Salvage at the War Office.

The National Salvage Department was concerned with the stimulation of salvage work already being performed throughout the country by municipal bodies or other Government Departments. It took direct action only when such bodies were unable or unwilling to undertake the work, and its activity in this direction was confined to the formation of a company with a capital of £50,000, allowed by the Treasury from Army funds. The company—the National Waste Products, Ltd.—was controlled by the National Salvage Council and absorbed the Army Waste Products Company, Ltd., which had dealt only with army salvage. The company had research laboratories and factories for treating condemned foodstuffs and butchers' offal and converting them into food for stock, or extracting from them raw materials such as oil. As a result of the department's activities, the salvage work done by local authorities was greatly increased and improved.

III.—Policy of the Department.

The policy of the Surveyor-General was to avoid interference with ordinary trade until it became essential in the interests of the nation. Conditions were, therefore, generally abnormal before control was assumed. This circumstance added greatly to the difficulties of the department, but, as a matter of policy, any interference with trade was postponed until it had become evident that conditions were resulting in unlimited opportunities for profiteering, or that supply could no longer be left to the discretion of private traders, to whom military requirements were unknown, since any error in judgment might have resulted in disaster. Where control was necessary, Government trading was avoided as far as possible, and alternative

[1] For the work done by the Ministry of Munitions in this connection, see Vol. VII, Part V.

methods of working through trade channels or by import and export licences were adopted. During 1917–1918, the increasing difficulty of securing tonnage made Government interference necessary in an increasing number of cases, in order to secure material in sufficient quantities, for private shippers were unable to secure freight. This usually necessitated bulk purchases by the department direct, and the initiation of trading accounts. The distribution of material so purchased and its utilisation to the best advantage involved a large measure of interference with trades, and placed on the department responsibility, not only for the continuance and preservation from ruin of large sections of the controlled trades, but also for the reasonable satisfaction of the wants of civilians. Schemes for rationing civilian supplies were evolved with the assistance of the trades concerned. In order to conserve supplies, considerable ingenuity was exercised in devising methods of economising scarce materials and substituting others more easily obtained. Standardisation was resorted to in a number of cases as a means of economising both material and manufacturing capacity. Another method adopted by the department to counteract the shortage of tonnage was to minimise the need for importation by encouraging the home manufacture of various substances which had previously been secured by importation.

The aim of the War Department in exercising control over industry, was not only to secure adequate supplies, but to obtain them at a reasonable cost. The latter object was gained in many cases by purchasing operations on a large scale, by which the first cost of material was much reduced. The power of requisitioning also had a beneficial effect in the prevention of speculation. Profiteering at intermediate stages of production was prevented by expert costing investigations, and large savings were effected by the elimination of merchants and middlemen. The method of fixing prices for contracts by investigating contractors' costs had been adopted by the War Department as soon as it was found that the normal method of securing reasonable prices by competitive tender was breaking down, owing to war conditions. The number of cases where reasonable prices could only be fixed by costings increased very greatly after the formation of the Department of the Surveyor-General of Supply, and the use of costing investigations was developed by the department. The department also found it possible in many cases to introduce new and more economical methods of production and to insist on the use of waste and substitutes, thus economising scarce and costly raw materials. Simplified collection and distribution tended to reduce cost, as well as to economise the scanty means of transport. Besides keeping down the prices of its own purchases the department was concerned to see that civilians were not exploited, thus the prices for civilian boots, clothing and jute goods were regulated.

The fact that selling prices of controlled materials, and, in certain cases, purchase prices also were fixed at the discretion of the Surveyor-General would have made it possible for the department to obtain large profits, but as the State was entering only temporarily into the field of trading, the value of private enterprise during and after

the war had to be considered, and the policy adopted was to sell as well as to buy cheaply and to keep down administrative and distribution charges.

In fixing prices, however, it was necessary to avoid loss. Care had to be taken to see that prices covered the full cost of the goods, the working expenses of the control and all trading risks, so that the amount paid should cover the full cost of production of the article. Submarine risks were very variable, being two per cent. in one commodity and 18 per cent. in another. The element of exchange was an almost incalculable factor, and other risks existed, especially in the case of Russian flax. Good luck and skilful management often resulted in a margin of profit considerably greater than was actually anticipated.

Prices were stabilised as far as possible, but since the purchase price of various commodities in foreign markets was beyond departmental control, periodical alterations of the prices fixed in this country were necessary. The policy followed was, by purchasing largely at opportune moments, and by a system of averaging, to moderate these changes and make them less frequent.

In fixing the price of material for civilian use, two classes of case arose. When the goods purchased could be quickly turned over to the consumer they were sold at prices providing merely for costs incurred by the department, but where, as in the case of Indian kips (many of which were unsuited for military demands and could therefore not be shipped), the department had, in addition to normal risks, to hold large quantities of goods which could not be immediately used and the ultimate selling value of which could not be estimated, the principle adopted was to sell the civilian supplies at market prices.

An important result of departmental control was a fair distribution of supplies, which secured the continuance of business organisations which were needed in post-war production, but which would have had little chance of survival had they been left to their own resources in the abnormal conditions of war production. Virtual control was assumed over the textile and leather manufacturing trades. To each mill or factory was assigned its due proportion of military orders, and such supplies of raw material as could be spared for civilian purposes were allocated according to the surplus available capacity of the factory. It was even found possible by careful allocation to supply wool for export, thus eliminating the economic and political difficulties which would have occurred as a result of intermittent embargoes on export. Special attention was paid to the stabilisation of wool prices over considerable periods in order to enable British manufacturers to compete in foreign markets. At the same time, a system of export licences prevented any purchasing on enemy account.

Throughout the period of control the department had in mind the needs of the reconstruction period. Trade patterns were in some instances adopted for Army use, partly with a view to facilitating the turnover to peace production, and the disposal of stocks in the hands of manufacturers on the cessation of hostilities.

It was impossible to avoid the infliction of great loss on certain importing merchants and commercial houses, in consequence of the activities of the Directorate of Raw Materials, though every effort was made to employ or adapt the established trading channels, as far as this was compatible with successful and economical working. In several important cases it was necessary to depart so widely from ordinary methods that great loss resulted to groups of traders whose services could not be utilised. Thus the purchase by the State and direct allocation to manufacturers of Colonial wool eliminated a number of merchants, whose activities had formerly been necessary for the efficient conduct of the wool trade.

The department encouraged the exchange of technical and scientific knowledge. The results of research undertaken by the department or by individual contractors were made known to all concerned. Thus, all dyers were informed of the results of investigations undertaken with the object of overcoming difficulties arising out of a shortage of various re-agents employed in dyeing, carbonising and stripping. As a result, the value of scientific research to industry was more generally appreciated by manufacturers. The assistance of the department, both with advice and financial accommodation, led to great improvements in methods of production, both by the more effective use of existing machinery and by the installation of more modern and efficient plant. Though the supervision of production by contractors for the War Office was not necessary to anything like the same extent as in munitions contracts, a certain amount was done by officers of the Department of the Surveyor-General of Supply. Thus, it was found that material for trench coats and aviators' requirements could not be obtained in sufficient quantities unless the work was directly supervised by the department, as the leather was of a nature not usually produced in this country and firms new to the work had to be persuaded to take it up; and, in spite of the numerous obstacles to production, the output of leather goods was actually increased by about 25 per cent. Another case of the kind was the organisation of the production of tool handles, which was so successful that the output of the trade doubled in six months.

The fact that the War Department absorbed the output of established industries, and was not, like the Ministry of Munitions, compelled to create new industries, to a great extent obviated the necessity for measures to increase the labour supply in those trades. On the other hand, the urgent demands for men for the Army made it necessary to prevent the removal of essential men from army contract work. With a view to ensuring that the needs of the Army were met to the fullest extent compatible with the necessity of ensuring that army contractors were not unduly denuded of efficient men, a census was taken in certain trades of the labour employed. This enabled the department to judge how far protection was necessary, and was also of assistance in allocating contracts with a proper regard to the distribution of labour.

IV.—Illustrations of the Work of the Department.

During the course of the war, the methods adopted by the War Department for securing supplies for the British Armies ranged from the normal peace time method of competitive tender to requisitioning the entire output of a commodity. In many cases Government action was taken only at the request of the industry concerned, but when control was once established it was found possible to direct demand into the channels most desirable from the point of view of transport and exchange. It was recognised that public opinion would not have supported the exercise of such powers by the Government until every possibility of obtaining supplies by the more usual means had failed. It is probable also that traders would not have been so willing to assist the Department of the Surveyor-General of Supply with advice and co-operation had the feeling existed that Government interference was unnecessary. The result was that control developed on no pre-ordained plan, but was exercised in a variety of ways, the department taking action according to the peculiarities of the situation in each individual case. In some cases, as in wool and wool textile production, it took the extreme form of absolute control of price and manufacture, from the purchase of the raw material to the production of the complete article. In other cases, the required degree of control was exercised by means of import and export licences, while in others, departmental action was confined to assistance in obtaining raw materials, advice as to methods of production, or assistance in the provision of freight.

It was often found that when once control had been initiated it was necessary to extend it still further to obtain the full benefits and to prevent the effects operating to the prejudice of particular branches of industry. Thus, though the control of leather was for the most part exercised through trade channels, the department was forced from time to time to make large purchases of materials for the account and risk of the State, and it also proved necessary to have part of the hides and skins so purchased tanned, curried or dressed by the trade on commission. These activities at one time or another included nearly every one of the varied branches of the leather trade. Control of certain kinds of leather led to the prohibition of the import of leather of all kinds except under licence, and prohibition of import was usually followed by the requisition of stocks held in the country to prevent undue inflation of prices. Thus when imports of jute were stopped in February, 1917, the department took over all stocks.

The department was always reluctant to undertake trading in any form. Its first aim was to assist industry to give its maximum contribution, and to encourage private enterprise to meet the needs of a difficult situation. Where for any reason the difficulties could not be overcome by private enterprise, purchase was undertaken or manufacture directed by the department only on the advice of experts. Even in cases where purchases were made under a Government account the ordinary trade channels were used if possible. Thus in the case of raw jute, purchases by the department were confined to estimated Government requirements, and were made through the trade, and though, during the early months of 1917, the shortage of tonnage

necessitated a restriction of imports on private account for civilian purposes, every effort was made to avoid unnecessary interference with private trade.

(*a*) NORMAL METHODS OF PURCHASE.

Wherever possible purchases were made by competitive tender. When the requirements of the Army formed a relatively small part of the available production of the country, and where, in consequence, there was effective competition, this method was the one best calculated to secure adequate supplies at reasonable prices and in a manner to inspire public confidence. In many cases it was possible to retain this method throughout the war as, for example, in the purchase of made-up clothing, where competition was so keen for army contracts that low prices were secured by this method of purchase. This system was supplemented by costings investigation where the prices quoted by manufacturers appeared unreasonable. Contracts to meet a steady demand, as for clothing, were when possible placed for a continuous weekly supply, subject to four weeks' notice of termination on either side, and usually contained a proviso securing the immediate cessation of cutting in cases where Government materials were supplied. Building bricks were also obtained under running contracts, where the quantities to be supplied were not fixed, but fluctuated according to the contract requirements of the Department. Most of these contracts were terminable at short notice and also contained a special war break clause.

A modified form of competitive tender was introduced for obtaining supplies of jam. Until early in 1916 supplies were obtained by the ordinary method of competitive tender, but in May a number of the most reliable contractors were selected to meet the whole requirement for the Expeditionary Forces. A committee of the firms was formed to buy fruit and thus avoid competition. The firms were paid the actual cost of containers, fruit and sugar used, and the cost of the transport of fruit and sugar and of the finished jam to military depots, and a fixed rate per 100 lb. for making the jam, this rate covering all costs and profit. For this item the firms quoted competitive prices and the quantities allotted to them were decided according to the rates quoted.

(*b*) SUPPLY UNDER DEPARTMENTAL SUPERVISION.

In cases where abnormal conditions prevailed various methods were adopted by the department to assist the trade to produce the required supplies.

Until the purchase of petroleum products in the United States was organised through the British Purchasing Mission, freight was the limiting factor in obtaining supplies. To overcome this difficulty supplies of petrol and lubricating oil were obtained through the medium of importing companies, importation taking place in Government freight. A similar method was adopted with tea. At first, requirements were met by purchase in the London market, but the difficulty of the freight situation led to the accumulation of stocks in the countries of origin, and a sharp rise in prices was beginning in 1917. A new

system was adopted by which contracts were made direct with the growers, through their representatives in London, for the purchase of tea f.o.b. Calcutta and Colombo, and the Government provided the freight.

The supply of sole and accoutrement leather was one of the chief anxieties of the department, but it was found possible by securing the co-operation of the trade to obtain supplies without financing by the State until the finished products were delivered to the military departments. The entire output of native hides was from May, 1917, secured for war purposes through an association of butchers, tanners and hide brokers, formed before the war. An allocation scheme based upon a complete series of statistical returns was formulated, by which tanners were allotted those classes of hides they could best handle for tanning into the varieties of leather specified by the department. By these means the raw material was controlled as completely as if the hides were purchased outright and afterwards distributed to tanners, while incidentally considerable railway transport was saved. Heavy hides for sole leather were imported from South America, and large purchases of preserved meat gave the department an effective instrument with which to induce the British meat companies in Argentine and Uruguay to dispose of their hides to British purchasers only, at very reasonable rates. These hides were purchased through the medium of the United Tanners' Federation, who financed the transaction throughout. The department also superintended the purchase of various tanning materials *e.g.*, myrabolams in India, wattle bark in South Africa, sumac from Sicily, and gambier from Singapore.

A scheme was inaugurated for the control of East Indian, Persian, Baghdad and other low quality wools, including wools of enemy origin captured in Baghdad, whereby such wool, though not actually purchased by the Government, was distributed to manufacturers through the trade organisations at fixed prices against Government orders or rationing certificates.

In the case of certain stores, such as packing cases, arrangements were made for the more important makers to specialise on the particular lines for which they were most suited, thus rendering production more efficient and economical. Running contracts for these special makes were then placed with them and continuity of output was secured.

Another means of partially controlling industry was through restrictions on import. During 1917, the shortage of freight necessitated a drastic reduction of imports, and by Order in Council the import of leather, hides and tanning materials was prohibited except under licence. The department was thus enabled to restrict the import of these materials to those suitable for military, or other essential purposes.

(*c*) DIRECT PURCHASE.

The necessity for Government action by direct purchase was due to various causes. Speculation in this country made Government interference advisable in certain cases, such as turpentine, where speculators had forced up the prices in this country to a very high level while the f.o.b. price in America remained low. Arrangements were

therefore made to meet the requirements of the War Office, both direct and indirect, by direct importation. The most usual reason for establishing Government trading was shortage of freight. The importation of raw jute from India in sufficient quantities to meet Government requirements for sandbags, oat and bread bags and Hessian cloth of all kinds began to present difficulty at an early period in the war. As long as the importation of jute was left in private hands it was difficult to secure jute goods on economical terms. Arrangements had been made with manufacturers to produce the goods on a basis of actual cost plus an agreed rate of profit. It thus became of the first importance to reduce and stabilise the price of raw material. The department therefore decided in August, 1916, to secure the raw jute required for Government contracts in India, and to supply manufacturers working on Government behalf. During the first season, 1916–17, the raw jute was purchased for the department by ten shipping firms, selected by the India Office, who shipped the jute from India at cost price without profit. After the end of the first season, Government requirements were secured in London in the ordinary commercial way from reliable firms who competed for the department's business.

For reasons of exchange and scarcity of freight, an embargo was placed on private imports of leather from the United States. Limited supplies of leather from this source were, however, essential owing to the great scarcity of upper leather, and purchases were made by the department through the British War Mission. These purchases were continued after the Armistice. The difficulty of obtaining upper leather through the ordinary channels led to extensive operations by the department in Indian kips (cow hides). Arrangements were made with the Indian Government for the purchase by the department of a large part of the output of the Indian tanneries, and the tanning of goat and sheep skins in that country was restricted in favour of kip tanning.

Tonnage difficulties led also to departmental dealings in certain tanning materials. The difficult shipping situation in 1917 prevented the provision of adequate supplies by private enterprise and fears of a shortage were entertained. In the case of quebracho, it became necessary to buy the extract f.o.b. Buenos Ayres, and to arrange shipment to this country, the department taking the risks of loss in transit. Direct purchase by the department had also to be made in the case of chestnut and hemlock extract from the United States, and of valonea from Greece, though in other cases, as has been seen above, a general supervision of the ordinary trade methods was sufficient to secure supplies.

Freight scarcity led early in 1917 to the assumption of complete control of the purchase and importation of Manila hemp. At the end of 1916, importation was falling below consumption and prices were advancing, as many shippers were unable to secure freight, and those who did so were able to command their own prices. The greater part of the supply was used either directly or indirectly for Government purposes, and in April, the department assumed control of the entire import for all purposes. The principal shipping houses in the

Philippine Islands were employed as Government buying agents, and the merchants and dealers in the United Kingdom were employed as distributing agents, both these operations being paid for at a fixed rate per ton.

In other cases departmental purchasing was necessitated by a world shortage of supply. This was the case with Java cinchona from which quinine is derived. Steps were taken by the department in 1917 to ensure the importation of supplies adequate for the requirements of both military and civil consumption. The largest operations due to this cause were the purchase of the Australasian wool clips of 1916–17 and 1917–18. The British clip amounted in 1915 to only one-ninth of the estimated consumption, and the importance of an adequate supply made special steps necessary. In December, 1916, the purchase was agreed with the Australian and New Zealand Governments of all their wool then remaining in the hands of farmers and all the wool to be shorn up to 30 June, 1917. The purchase price was fixed at 55 per cent. above the level of 1913–14 prices, and in the case of Australia it was subsequently arranged that this should mean a price of 1s. 3½d. per lb., greasy weight over the whole clip. The Government of Australia drew up baremes, or detailed schedules of prices, according to quality, for the purchase of the wool from the individual farmers, subsequent adjustments being made to bring the total price for the year to 1s. 3½d. placed on shore in Australia, with an extra allowance of ⅝d. per lb. for administrative, holding and other charges up to shipment. It was further agreed that while this price should apply to all wool used for British Government purposes and for certain Allied military purposes, one-half of the profit on sales of surplus wool effected by the British Government should be returned to the Dominion Governments. The Dominion Governments made efficient arrangements for collecting and storing the wool and shipping it to the order of the British Government. The Directorate of Raw Materials was responsible for arranging transport and distributing the wool to the best advantage.

In the middle of 1917, the contract for colonial wool was continued for another year on the same terms. In 1918, further contracts were negotiated with the Governments of Australia and New Zealand for the purchase of their entire surplus wool clips for the whole of the remaining period of the war and for one entire wool year thereafter, it being subsequently agreed that these contracts should be interpreted to include all wool appraised up to 30 June, 1920. The price and profit-sharing arrangements were continued without change, except for a concession to meet the special conditions of New Zealand wool. Part of the South African clip for 1917–18 was purchased on similar terms. The British Government wished to acquire the whole clip, but South African growers were able to dispose of large quantities to American and Japanese purchasers on better terms than those offered by the British Government, and the offer was consequently not accepted. Such portion of the South African clip as was offered by individual growers was, however, accepted at the same price as that given for Australasian wool.

The Icelandic and Falkland Island clips were also bought, the chief reason for these purchases being to prevent their acquisition by the enemy.

The conditions under which the Department assumed control of Russian flax and of flax-seed were peculiar. During 1916, military demands absorbed a large proportion of the total available supplies, the largest source being Russia. Conditions in Russia were such that it would have been exceedingly hazardous to rely upon importation through private channels. The Baltic was closed to commerce, and all Russian flax had to be obtained through Archangel, and the interruptions consequent on the short shipping season, and danger from enemy action seriously interfered with supplies. It was decided that adequate supplies could only be secured by establishing Government buying agencies in Russia, and making special arrangements through the Ministry of Shipping for the carriage of flax by sea. Purchasing was entrusted to four leading British houses in Russia, and buying centres covering the whole of the Russian flax growing districts were allotted to branches of these houses. By careful arrangement, three successive crops—1916, 1917, 1918—were purchased on very advantageous terms. The invasion by the Germans of the north-western provinces of Russia, and later the Bolshevik Revolution caused very considerable anxiety as to the safety of the stocks of flax belonging to the department in North Russia, but eventually all flax paid for out of public funds was duly shipped.

The department also undertook the supply of flax seed, with the object of obtaining maximum production in Ireland and elsewhere. The seed was purchased in a dozen different countries, sometimes at extortionate prices, owing to the great demand. The plan of sowing Japanese flax seed in Canada and bringing the first crop of seed for sowing in the United Kingdom was successfully adopted.

(*d*) REQUISITIONING.

The procedure for the requisition of entire output at first rested on no statutory authority, but was put into force by means of negotiation with individual contractors or trade associations. Owing to the growth of the Army and the increasing difficulties of supply, voluntary methods were found inadequate and powers were obtained under the Defence of the Realm Act, by which a firm's output could be requisitioned and the price fixed on a basis of cost of production, plus a reasonable profit. Corresponding powers were obtained in regard to stocks of manufactured goods held by any person other than the manufacturer, and all non-manufactured commodities such as agricultural produce by whomsoever held. These powers were first obtained on the initiative of the War Office, though they were afterwards widely used by both the Admiralty and the Ministry of Munitions. Moreover, their mere existence, apart from their actual use, was found to be a safeguard to the public purse.

Powers of requisitioning under the Defence of the Realm Regulations were resorted to only in extreme cases. In the case of wool, military needs became very urgent at an early period in the war,

and when the demand reached its maximum point over three-quarters of the available stocks of wool and the existing manufacturing capacity had to be devoted to meeting it. Early in 1916, it was decided to requisition the whole of the British wool clip. This required the improvisation of complicated machinery to deal with the purchase of about 140,000 individual clips direct from the farmers. The 1916 clip was purchased on a basis of 35 per cent. above the average price ruling for each type of wool from June to July 1914. The country was divided into areas—ten in England, two in Wales, one in Scotland and two in Ireland—and experienced wool buyers were appointed as Deputy Executive Officers in charge of the areas. These officers were responsible to the Chief Executive Officer in London. Wool merchants with the necessary qualifications (who were remunerated by a fixed rate of commission on the weight of wool handled by them) were authorized to take up and value the wool on behalf of the department, in accordance with a schedule of prices drawn up by the technical officers of the department, in consultation with a trade advisory body. The merchants were required to grade all fleeces purchased by them in accordance with fixed standards. The average price paid for each grade of wool, June to July 1914, was ascertained as nearly as possible. The purchasing operations of the wool merchants were supervised by the Deputy Executive Officers. Payment was made direct to the farmer by the Finance Branch in London, on the certificate of the Deputy Executive Officer concerned, except in Ireland, where payment was made through authorised merchants. Skin wool, *i.e.*, wool pulled from the skins after slaughter, was also requisitioned. A Top-making Department was set up in Bradford to arrange for the manufacture of the combings into tops and noils at fixed rates of commission, based on ascertained costs. Schedules of prices were drawn up for wool and tops, and spinners and manufacturers were supplied with the material they required month by month at these fixed prices.

The home clip was again requisitioned in 1917. Owing to the increased costs of production, the price of this clip was fixed at 50 per cent. over the 1914 prices. Arrangements for purchase were substantially the same as in 1916, but the experience gained in that year led to some improvements in method. A third purchase—that of the 1918 clip—was made at prices 60 per cent. above the 1914 level.

Requisitioning on a smaller scale was carried out with other supplies. Asbestos and Portland cement were obtained by this means during 1917, and the system was later extended to roofing felt, felt fibre and bitumen. The stock and output of certain large brickfields were also secured by requisitioning. In October 1917 in consequence of air raids in the London area, supplies of service dress uniforms had to be requisitioned in Leeds and other provincial districts as a temporary measure, and, owing to the greatly increased demand for oilskin clothing, practically the whole manufacturing capacity of this trade was requisitioned.

From the beginning of 1916 onwards, supplies of hosiery were obtained by requisition. The amount of profit was determined on a pre-war production basis, the manufacturer receiving as profit an

amount per garment corresponding to that which he would have earned under normal conditions. A series of standard maximum prices for the various items in the cost of production was agreed with local advisory trade committees.

Scotch blast furnace oil was requisitioned in 1916. This valuable oil, which is the raw material in the manufacture of disinfectants, was being used as a fuel oil before the extraction of the tar acids, though the spent oil was equally good fuel. The requisitioned oil was passed by the department to tar acid distillers who agreed to extract the tar acids and fractionate them, selling the high-boiling fraction to the department. The spent oil was sold to the Ministry of Munitions. By this means adequate supplies were ensured and a reserve built up, so that in 1918 the department was able to release large quantities of tar acids for civilian and even for export purposes.

(*e*) METHODS OF DISTRIBUTION.

Means had to be devised for distributing among manufacturers the raw materials acquired by the department, either by direct purchase or requisition.

Wool was distributed on priority 1 to Government contractors, priority 2 for the manufacture of standard cloths, blankets, flannel hosiery, etc., for civilian use, and priority 3 to manufacturers for ordinary civilian trade. The wool was issued at prices which remained fixed for specified periods. The periods varied according to circumstances, and were fixed with the object of stabilising trade, and enabling manufacturers to compete where possible for export trade. As an illustration of the success with which prices were stabilised, prices for wool issued to civilian trade were maintained at the same level from 10 January to 30 November 1917. Wool was distributed to a small extent in public auction rooms at fixed prices, the wool being allotted by the London Wool Selling Brokers' Association to approved users against rationing certificates for civil trade. But the greater part of the Colonial wool was distributed through the Distribution Sample Warehouse at Bradford, and of the British wool by allotment through the British Wool Distribution Section in London.

Wool was issued at two price levels : (1) for Government contracts at a price based on cost, plus a margin for administrative and other charges, and (2) for civil use at the market price, which, during 1917, was about 20 per cent. above the military issue price. There were disadvantages in selling thus at two prices, and since freight rates and other expenses had increased, it was decided in August 1917, to raise the issue prices for wool for Government contracts to a parity with civil issue prices.

In the case of tanning materials and hemp imported by the department, distribution was arranged through ordinary trade channels at fixed prices, covering all incidental expenses.

Russian flax was distributed on a rationing system. Spinners were supplied according to the capacity of their spindles, at prices fixed on a basis of a reasonable margin over the purchase cost of current shipments. The spinners and manufacturers were bound to

undertake Government orders to the full required extent, before undertaking any civilian business. The spinners' costs for Government work were checked by the experts in the flax office. After direct and indirect Government wants had been supplied, the work next in order of priority was class A work, such as canvas for ship repairing firms. Next came material essential for keeping other industries going, such as filet cloths for sugar and oil works, canvas for biscuit-making machines, and various fine goods for hospitals. After providing these requirements, manufacturers were at liberty to sell their surplus production at their own prices. Such surplus was in practice small, and the selling price was regulated by current Government prices, which were well known.

The arrangements for the distribution of raw jute were special, owing to the fact that part of the jute was purchased by the department and part by the trade. Each spinner was rationed according to his consumption in 1916, the ration to each spinner bearing the same proportion to this consumption as the tonnage available bore to the total tonnage imported in 1916. Of this ration, the spinner received half from the department's purchases and he received licences to import the remaining 50 per cent. These licences carried the right to an equivalent quantity of freight space, and provided the only method by which jute could be shipped to this country. By this method consumers were not forced to compete for freight space, but, on the other hand, the shippers who had large quantities of jute available in India had to compete for business, and prices were thus kept at a reasonable level.

(*f*) Encouragement of Home Manufacture.

Certain drugs and chemicals were before the war entirely imported from abroad, largely from enemy sources. It therefore became necessary for the department to encourage and stimulate home manufacture where possible. The total requirements for phenacetin and aspirin were, by the spring of 1918, being produced in England at prices, in the case of aspirin, one-eighth, and in the case of phenacetin, one-third of the prices which ruled when the department started to encourage home manufacture. The demand for potassium permanganate, both for military and civilian purposes, was very great, and all requirements were at first imported. The result was a great increase in price, but the steps taken by the War Department to initiate, assist, and develop the manufacture at a works in the Midlands were very successful.

The use of home-grown tanning materials, such as oak and larch bark was encouraged by the department, in order to save importation of materials of foreign origin. It requires two or three tons of tanning material to produce one ton of leather, so that economy in import was very essential.

(*g*) Standardisation and Alteration of Specifications.

It was found possible by standardising certain stores which were required in large quantities, and by modifying army specifications to conform with manufacture for civilian use, to effect considerable saving in cost, and to facilitate and speed up production. The shortage

of timber caused attention to be paid to the need for economy in packing cases, as soon as the department assumed responsibility. Some economy was effected by modifying existing specifications and substituting crates for cases, and experiments were made with strong standardised cases of graded sizes suitable for nesting, in order to facilitate return from abroad. Many of the tools, cutlery, and other supplies used in the Army before the war were of a special type, but the department found it possible to accept trade articles, as, for example, in the case of the army knife. This is required to serve a variety of purposes, and the original was a large and unwieldy implement, not likely to find a market outside the Army. Modifications of pattern which made it suitable for civilian supply were introduced, so that the machinery specially set up for production in very large quantities would still be of use after the war.

Various steps were taken to secure economy in the production of army clothing. Mercerised cotton was substituted for silk in the sewing of garments, hand work was abolished in certain cases where machining was possible, and arrangements were also made for the supply from the Royal Army Clothing Department of all sewing materials required for Government contracts, thus eliminating competition between contractors. A special committee of experts was appointed to undertake a thorough review of the patterns and specifications of army clothing. Various simplifications were made, leading to economy in material and manufacture, which had the great advantage of reducing the demand on a rapidly shrinking labour market.

Drastic revision was also made in the specification of many fabrics, eliminating where possible the use of raw wool and substituting waste and by-products. New standard specifications were made with the assistance of the Specifications Committee of the trade, and a scheme of waste control established, by means of which, prices of wool by-products were fixed. Considerable standardisation was achieved, and methods of production were consequently simplified, and economy in use of raw material attained. Hundreds of different types of felt were originally produced for different purposes, from felt socks to wads for shells and washers for guns. It was found that in connexion with contracts for engines, shells, etc., production was uneconomic, and sub-contracting existed on a large scale. Felts were standardised into four types, and the use of raw wool was economised in two of these types by the substitution of wool waste and vegetable fibre. When the difficulty of obtaining silk cloth for container bags rendered the substitution of all-wool cream serge essential, it was found that adequate supplies of this serge were unobtainable and makers would not guarantee that the material would be strong enough. The Raw Materials Directorate then took over supply, and after investigation of the special requirements, in consultation with Woolwich experts, yarn tests were made, standard yarns established, and the whole cloth reconstructed, with the result that ample stocks became available.

Output was greatly increased by standardisation in the case of surgical needles. With the co-operation of manufacturers a number of redundant types were eliminated. Similarly arrangements were

made for the production in bulk of specified dyes, while a number of other dyes hitherto used were entirely discontinued. The adoption of a common specification for soap resulted in a large increase in output, and economy of the scarce oils and fats required in manufacture.

(*h*) Economies and Use of Substitutes.

The tonnage situation during 1917 and 1918 necessitated the utmost economy in imported materials and the use where possible of home-produced substitutes. Some of the most important of these may be mentioned. The substitution for fustic (dye) of synthetic yellows of equal fastness manufactured in this country resulted in the saving of many thousand tons of shipping. The use of certain acids was almost entirely eliminated, and such by-products as nitre cake were substituted. Thus, for dyeing purposes, the use of sulphuric acid, acetic acid, and formic acid, was almost dispensed with, and the use of sulphuric acid for the carbonisation of cloth was much reduced.

The heavy demands for steel for munitions purposes necessitated economy in the use of tin plate. To manufacture 20 tons of tin plate about 28 tons of steel are required and thus the packing of the jam ration alone entailed the consumption of 1,200 tons of steel monthly. Experiments were undertaken with a view to substituting wood pulp board for tinplate in the packing of food stuffs. The food container had to be airtight and damp proof, and in the case of the jam container had to withstand a temperature of 160° F. A suitable composition was found after several months of experimental work, and proved so successful that it was used on a large scale for civilian purposes as a substitute for tin.

Investigation by experts led to the adoption of a new and much cheaper blend for great coating cloth, in which certain waste products were used, thus economising raw wool. Again the necessity for saving flax for aircraft purposes led to the restriction in the amount used for linen thread. The administration of the Thread Orders was undertaken by the department in co-operation with the Flax Control Board, care being taken to ensure that efficient substitutes were available before the supply of flax was wholly cut off.

A large reduction in the weekly requisition for army boots was brought about by organising an efficient system of repairing. Repairing depots were set up, both at home and in the theatres of war, while at the same time, boot repairing in the units was developed. These measures effected large economies in the use of leather, more particularly of upper leather, of which, 4 ft. are required for a new pair of boots.

A certain economy in timber was effected by dispensing with packing cases for certain stores, *e.g.*, bacon, which was baled instead of being packed in boxes.

Reference has already been made to the work in connexion with economy of materials done by the Army Salvage Department and the National Salvage Department.[1] Salvage depots were set up

[1] See above, p. 131.

all over the country for the treatment of material which was either unfit for army use, or needed renovation before use. Materials which could be re-utilised, such as waist belt hooks from worn out tunics, were removed and the remainder cleaned and reduced to a marketable condition for disposal as rags for blending with new material. Waste cuttings and stores rejected on inspection were purchased from contractors and treated in a similar manner.

The National Salvage Department carried out a good deal of experimental work on fuel economy, and the treatment of refuse to extract useful products. Investigations into the relative costs of various methods of dealing with household refuse proved that screening and sorting were more economical than any other. By this method paper, tins, bones and rags and large quantities of cinders of high calorific value were recovered and re-utilised. Successful experiments were carried out with various methods of de-rusting and re-conditioning metal tools, machines and milk churns, and markets were found for a number of waste products.

(*i*) Restriction of Consumption.

Early in 1917 it became necessary to devise a system of rationing wool and tops for civil purposes. With this end in view a priority scheme, which had been drawn up by a committee of merchants and manufacturers in consultation with the officers of the department, was put into operation. The United Kingdom was divided up into areas and a District Priority Committee was set up in each area, representative of manufacturers, merchants and operatives. The work of these committees was co-ordinated by a Joint Priority Committee, consisting of representatives of each of the District Committees. The quantity of raw material determined by the department to be available for civilian purposes was distributed by the Joint Priority Committee to the District Priority Committees. In a similar manner, the yarn produced was rationed to manufacturers. It was also decided on the recommendation of the Central Wool Advisory Committee to limit the weekly hours of work on weaving and spinning. As all army orders were executed in priority, the effect of this Order was to throw on civilian trade the whole of the reduction in consumption thereby effected.

With a view to economy in the use of leather the manufacture of women's boots with leather uppers over 7 in. in height was prohibited, and a circular was widely published throughout the trade, urging repairers to use the smallest possible amount of leather in repairs, *e.g.*, to patch a worn sole rather than replace it by a new half sole. An important measure to ensure economical use of leather was taken in April, 1918. Under this "Certificate Scheme" no leather could be obtained for the manufacture of boots, either for Government or civilian purposes without the production of a certificate endorsed by the department, and any waste leather remaining after manufacture could be disposed of only under instructions from the department.

(*j*) Regulation of Civilian Supplies.

The embargo on imported leather threatened to create a shortage of boots for civilians, and consequently a scheme was instituted to provide the civilian population, more especially the workers on munitions and in agriculture, mining, etc., with boots of good quality at reasonable prices. These "wartime" boots were made by all manufacturers in the country to the extent of one-third of their capacity, according to a number of approved patterns. The boots were priced so as to allow a profit of 5 per cent. to the average manufacturer, and the distributors agreed to handle them at an addition of 33⅓ per cent. on manufacturers' prices.

A somewhat similar scheme was adopted for the provision of cloth for civilian wear, by which arrangements were made for the production and distribution of suits, overcoats, blankets, flannel and hosiery of standard quality and prices. The trade financed the whole scheme, and the part played by the directorate was to bring together the various sections of the trade in order that they might arrange a voluntary scheme. The cost of administration of the scheme was covered by the addition of 1d. a yard to the manufacturers' cloth prices.

V.—Relaxation of Control.

After the Armistice, when the formation of a Ministry of Supply was under consideration, the Department of the Surveyor-General of Supply (with the exception of certain sections of the Salvage Branch and the section dealing with building works contracts) was transferred to the Ministry of Munitions, and Lord Inverforth, who had been appointed Minister in January, 1919, added his former responsibilities to his new office in March of that year.[1]

War Office controls were in all cases continued for a few months after the Armistice. The Directorate of Raw Materials decided to abolish, on 31 March, 1919, all Army Council Orders relative to the sale or use of wool, and to take such steps in the matter of sale of Government-owned wool as would conduce to the most rapid return to normal peace-time trading conditions. It was announced that the British wool clip of 1919 would not be purchased by the Government; it could be dealt in without restriction, and there would be no further interference with dealings in Indian wool. All import restrictions were abolished at the end of February, 1919, but at the special request of the Wool Council certain restrictions on export were continued until January, 1920, since local scarcity, due to shortage of freight, had not been remedied. At the latter date nothing remained of wool control except in connection with the Imperial contracts for the purchase of Australasian and South African wool.

The leather trade expressed a desire that Government control should not be removed too rapidly, and it was thought that international control would be desirable. International control did not materialise, but departmental control was continued for a time. The

[1] Sec./Gen./855. For further details see Vol. II, Part I, Supplement.

Treasury desired to restrict the importation of leather from the United States, and the department bought only strictly indispensable supplies, but on 15 June, 1919, importation was made absolutely free. By the end of June freedom had been restored to a large extent throughout the leather trade, and only at the request of the Food Ministry, who considered that British hides should be taken over at a uniform price, was the control of native hides continued until the end of 1919. Restrictions on dealings in raw and tanned hides from India were continued. The tanning of cowhides in India had been artificially stimulated during the war, and the position of stocks in the United Kingdom, taken in conjunction with the position of tanners in India, made it necessary to consider very carefully the steps to be taken during the transition period.

The prices of all fibres were controlled for some months, but arrangements were made for their release during March and April, 1919. Rationing of jute had already been terminated by the middle of March and the department was no longer making purchases in India. All restrictions on dealings in hemp had been removed by 14 March.

With regard to War Department stocks, it was decided after due consideration that Government stocks should in no case be sold during the transition period at any price higher than the lowest estimate of replacement value, and that where it seemed to be necessary for the maintenance of employment and the re-establishment of trade on a sound basis, issues to manufacturers should be made at still lower prices. Consequently, stocks of jute and manila hemp were realised at low prices during a temporary slump after the Armistice, and in the case of flax and other commodities, the issue prices moved slowly behind the open market, which in general advanced sharply as controls were released. It seems not improbable that the department carried its attempt to keep down prices too far and that manufacturers and traders reaped an undue proportion of the benefit of the low prices at which Government stocks of raw material were sold. After the middle of 1919 prices rose so rapidly that the policy of disposal had to be changed, and the department from that time fixed selling prices on commercial lines, obtaining the full market value as far as was consistent with the rapid realisation of its stocks.[1]

The policy adopted in administering the stocks of wool was to keep British markets in contact with other markets by encouraging unrestricted dealings in all classes of wool save the Government-owned stocks of Australasian wool, which amounted to about half the world production. From 1 April, 1919, auction sales became the chief channel of distribution of Australasian wool, but since it was impossible, owing to physical difficulties, to market the whole of the Government stock by this means, it was agreed, on the advice of the Wool Council, that the system of issue at fixed prices which had been in force for over two years should be continued up to November, 1919, and should apply to a moderate quantity of wool to be distributed direct to manufacturers and spinners in Great Britain and to the

[1] Cmd. 788, 1920.

Governments of France, Italy and Belgium, for distribution in like manner. The issue prices for the period April to November 1919 were fixed at 7½ per cent. below those ruling for the preceding twelve months, with the object of stabilising prices at a lower level, since it was anticipated that a period of cheaper freights and lower prices for material was likely to ensue. This anticipation was not realised in the case of higher grade wools, the demand for which, after the Armistice, was considerably in excess of the world's production, so that the Ministry's attempt to exercise a moderating influence on prices was defeated and the top-makers and spinners to whom the wool was allocated, rather than the consumers, benefited by the issue of wool at reduced prices. Owing to the keen competition at auction sales and the high prices paid, the scheduled issue prices were found to be much too low, but it was difficult to alter them in view of the announcements which had been made by the Wool Council.[1] The labour members of the Wool Council urged in June, 1919, that complete control should be re-established, which would in effect have amounted to the nationalisation of the woollen trade. This was not accepted, but allocations at the reduced prices to the extent of about 30 to 35 per cent. of requirements were continued for a time in the hope of benefiting the consumer. This system was discontinued in November, and Australasian wool was from that time distributed entirely by auction.[2]

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[1] HIST. REC./R/600/19.
[2] (Printed) *Weekly Reports*, June–September, 1919, *passim*.

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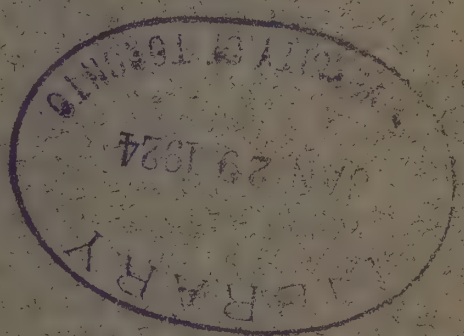
HISTORY OF THE MINISTRY OF MUNITIONS

VOLUME VII

THE CONTROL OF MATERIALS

PART II

IRON AND STEEL



1922

Volume VII

THE CONTROL OF MATERIALS

PART II

IRON AND STEEL

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CHAPTER I.

THE WAR DEMAND FOR STEEL.

I.—The Position in 1914.

Great Britain was in many ways well equipped for the position into which she was forced at the outset of the war. Although she was no longer the greatest producer of iron and steel, and in 1913 only accounted for 14 per cent. of the world's output against 25 per cent. produced by Germany and 40 per cent. by the United States of America, she still remained the second largest exporter of iron and steel, with a total export of 5,049,000 tons, Germany exceeding this figure by more than half a million tons. The year 1913 had been a boom year in the industry and everywhere a period of depression was expected. Germany and Belgium were exporting their surplus stocks of steel at very low prices and, in 1914, British steel-makers were beginning to feel the effects of this competition. The import of cheap foreign steel into Great Britain herself had begun, and although the steel-making capacity of the country was not yet affected, production was lessening, with the result that there were exceptionally large stocks of pig-iron in the hands of ironmasters and merchants at the beginning of the war.[1] The loss of the pre-eminent position held from 1870 to 1880 was partly inevitable in face of competition with the population and resources of the United States and Germany, but it was also due to the early development of the industry in Great Britain before modern methods had arisen. This led to the continued existence of small steel works, scattered about the different steel-making districts, often without any close connection with blast furnaces. In the later developed industry of her competitors, large co-ordinated works had been built and far more encouragement had been given to laboratory research, the introduction of new methods and the renewal of plant. Certain British steel works, however, were equipped with the most modern plant, laid out on scientific and economic principles, while the pre-eminence of the Sheffield manufacturers of special steels was still unrivalled.

The evidence given before the Iron and Steel Industries Committee in 1917, emphasised the fact that, apart from these firms, British manufacturers were behind other countries in research, plant and method. Many of the iron and steel firms were working on a small scale, with

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[1] *Iron and Steel Trades during the War*, by M. S. Birkett. (Hist. Rec. /R/1810/79.)

old systems and uneconomical plant, their costs of production being so high that competition with the steel works of the United States and Germany was becoming impossible.[1]

The country depended on some 59 firms for its output of commercial steel, the remaining 28 steel firms being engaged in special branches of the trade where economical production was not of the first importance. The 59 firms were grouped as to output as follows :—

1	firm	produced	over	10,000	tons	of steel	per week.
8	firms	,,	5,000–10,000	,,	,,	,,	,,
15	,,	,,	2,500–5,000	,,	,,	,,	,,
29	,,	,,	1,000–2,500	,,	,,	,,	,,
6	,,	,,	under 1,000	,,	,,	,,	,,

A similar state of things existed among the ironmasters. Ninety-one firms made pig-iron only, operating 301 furnaces per week with an average production of 568 tons per furnace per week, or not much over a quarter of the output of a modern and efficiently worked furnace using ordinary British ores. Some firms were operating furnaces 70 years old, and many had quite out-of-date plant.[2]

Another factor, also due to the early development of the industry in Great Britain, militated against the easy turnover to war conditions. The acid process of steel-making, which developed some 25 years before the basic process, was firmly established, especially in Scotland and Wales, and this had led to the use of a large quantity of high grade imported ores, which were more suitable than the majority of British ores for conversion into steel in acid furnaces.[3] This course was financially possible owing to the geographical position of the ports of entry, close to the coal-fields, so that transport of the ore involved only low sea freights. As will be seen below, this dependence on foreign ore was one of the chief difficulties that faced the Ministry of Munitions in the supply of steel for munitions. On the other hand, the United Kingdom was well endowed with supplies of coal, coke and refractory materials, and the only essential materials not to be found in the United Kingdom in sufficient quantities were magnesite, manganese ore and alloys for special steels.

The home production of iron ore in 1913 amounted to 15,997,328 tons,[4] but of this only 1,767,079 tons, the output of the Cumberland and Lancashire mines,[5] was hematite ore, similar in analysis to the

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[1] *Minutes of Evidence taken before the Iron and Steel Industries Committee*, 18 *April*, 1917. Copy in Hist. Rec./R/1810/8. The output of blast furnaces in the United Kingdom as compared with the output in Germany and the United States was very low, and the annual output of the workmen in the pig-iron industries was 380 tons per head as compared with 599 tons in the United States.

[2] Hist. Rec./R/1810/13.

[3] *Ibid.*, p. 16.

[4] Hist. Rec./R/1810/15.

[5] *Iron and Steel Industry*, 1914–18, by F. H. Hatch, Ph.D., p. 122 (Copy in Hist. Rec./H/1810/5).

imported ore. The deposits of this ore occur in carboniferous limestone and the mines lie between Lamplugh in Cumberland and Ulverston in Lancashire. The ores are remarkably free from phosphorus and sulphur and can, therefore, be converted into a pig-iron suitable for the acid Bessemer process. The ores range in composition within the following limits :—

	Per cent.	Average Per cent.
Iron	40—57	50
Silica	6—23	13
Phosphorus	0·005—0·022	0·013
Moisture	4—9	5·6

A small amount of hematite and brown ores occur in South Wales and the Forest of Dean.[1]

About 70 per cent. of the home ore supply, however, was obtained from the Jurassic ironstones, distributed in the following districts :— Northamptonshire and Rutlandshire, Cleveland, Leicestershire and South Lincolnshire, Oxfordshire and North Lincolnshire. The analysis of the raw stone, which contains a high percentage of sulphur and phosphorus, is as follows[2] :—

	Northants and Rutlandshire.	Cleve-land.	Leics. & S. Lincs.	Oxon.	N.Lincs.
Iron	32·5	28·1	25·2	24·0	22·7
Manganese	·24	·41	·23	·27	·96
Silica	14·7	11·8	10·9	10·2	8·1
Alumina	6·1	10·2	8·0	7·6	5·1
Lime	2·7	4·7	9·6	12·2	18·2
Magnesia	0·4	3·5	0·6	0·6	1·0
Sulphur	0·10	0·26	0·11	0·06	0·16
Phosphorus	0·60	0·47	0·25	0·23	0·31
Moisture..	15·2	6·8	16·4	15·6	10·7

The ironstone obtained from the coal measures of Scotland is also high in phosphorus and sulphur content. In consequence, 33 per cent. of the ore used in the conversion into pig-iron was imported, and, owing to the higher grade of the imported ore, the value of the pig-iron produced from it was equal to that of the pig-iron produced from double the quantity of British ore. The sources of supply were little

[1] *Iron and Steel Industry*, 1914–1918, p. 80.

[2] *Jurassic Ironstones of the United Kingdom*, p. 9., by F. H. Hatch, Ph.D. (HIST. REC./R/1810/60).

affected by the military operations, only 5 per cent. of the imports having come from the occupied districts of France and Belgium. In 1913 imported iron ore came from the following countries :—

	Tons.		Tons.
Spain	4,714,039	Holland	27,330
Algeria	763,258	Belgium	23,155
Norway	489,999	Chile	13,778
Sweden	366,693	Canada	11,542
France	327,234	Italy	10,853
Tunis	279,071	Germany	10,387
Greece	217,142	Portugal	4,046
Newfoundland	100,346	Asiatic Turkey	3,542
Russia	79,244	Various	590

In all, 8,028,532 tons came into the country in 1913,[1] including 586,283 tons of purple ore obtained from imported pyrites. A small amount of ore was exported and there remained 24,019,482 tons of ore available for smelting.

In the same year (1913) 10,260,315 tons of pig iron were manufactured, but of this more than a third was converted into forge and foundry iron. The details of pig iron production were as follows[2] :—

	Tons.
Hematite pig iron	3,604,823
Forge pig iron	1,300,787
Foundry pig iron	2,500,760
Basic pig iron	816,891
Ferro-chrome, Ferro-silicon, Spiegel-eisen, Ferro-manganese	324,145
Pig iron sent molten to steel furnaces	1,712,909

The production of steel ingots and castings reached the figure of 7,664,000 tons, of which about 60 per cent. was acid steel, made from hematite pig iron with the addition of a maximum of 30 per cent. of scrap steel.[3]

The importance of steel as one of the essential materials for the supply of munitions seems to have been ignored to a remarkable extent by the military and naval authorities of the Allied Powers. This was less surprising in the case of Great Britain, where supplies of steel had always been greater than the requirements of any military campaign, than in the case of France and Italy. For the last twenty-five years the French General Staff had been preparing plans to meet an attack from Germany based on the assumption that operations would begin from Alsace and Lorraine, but apparently no cognisance was ever taken of the fact that the Briey ore fields, which produced 80 per cent. of

[1] Hist. Rec./R/1810/15.
[2] Hist. Rec./R/1810/15.
[3] *Iron and Steel Industry*, 1914–18, p. 120.

French iron ore, were commanded by the enemy fortress of Metz. Italy, with practically no natural resources of iron or fuel, had maintained military forces beyond her financial powers, depending upon her Allies of the Triple Alliance for steel and coal. In consequence, both Allies turned to Great Britain to supply them with steel, and when her resources were insufficient they had to obtain supplies from the United States of America at inflated prices. The Governments of both countries, however, did all in their power to increase their production of steel so far as it was possible in war time.

The supply of steel presented no special difficulties until the middle of 1915, when the task of securing adequate supplies, not only for the increased munitions programmes, but for Admiralty requirements and civil needs, fell to the Ministry of Munitions, and from June, 1915, a section existed in the new Department with this special responsibility.[1] Almost immediately this responsibility for supply involved the control of prices and manufacture, the development o new and existing sources of output, the investigation of new methods and possible substitutes, and special arrangements for the supply of the ferro-alloys, refractory materials, limestone and other materials.

II.—Shell Steel Programmes.

The supply of shell steel practically monopolised the energies of the Steel Section of the Ministry of Munitions during 1915. The position with regard to the supply of steel for British shell and also for the fulfilment of the contracts already placed by the French Government in Great Britain were reviewed in the first place, and plans formulated by which the increasing demands of both armies for shell might be met. The department decided to enlist the help of the steel-makers in increasing the supply of steel. Conferences were held with the steel-makers at the Ministry of Munitions and by 16 June, 1915, a committee of steel-makers was appointed, representing firms in the chief centres of the industry.[2] The committee formulated a scheme with special reference to the requirements of 1915, and recommended that the country should be divided into three districts—Scotland, the

[1] The Steel Section, under Col. (later Sir) W. C. Wright, was originally part of the Raw Materials Branch, but by the middle of 1916 its scope had so increased that the original plan of organisation had been outgrown. The staff was inadequate and the separate sections were working independently of each other, especially in the matter of statistics. A committee was appointed to enquire into the organisation, and as a result of their report a separate Iron and Steel Production Department was formed in August, under Mr. (later Sir John) Hunter (HIST. REC./R/263·35/6, 8; C.R. 4467, 5087). The organisation of the department at the time of its fullest development is shown in Appendix I.

[2] The members were Mr. G. Scoby Smith, chairman, of Messrs. Bolckow, Vaughan & Co., Middlesbrough; Mr. B. Talbot, Cargo Fleet Iron and Steel Co., Ltd., Middlesbrough; Mr. G. Hatton, Earl of Dudley's Round Oak Works, Ltd., Brierley Hill; and Mr. A. Colville, of Messrs. David Colville and Sons, Ltd., Motherwell, Scotland. Sir L. Llewelyn's Papers, 20. (These unregistered papers are now filed in the Archives Registry.)

North of England and the Midlands, including South Wales. The committee was to obtain from each maker an estimate of the total quantity per week of shell steel which the firm could place at the disposal of the Ministry. Working on these estimates the committee would apportion the Government requirements to each district and in turn each district would apportion its quantity amongst its own makers. Armament firms were to be excluded from this scheme, but the steel supplied by other makers to the armament firms was to be included. The price at which steel was to be supplied was to be a uniform one, and had been agreed upon between the steel-makers and the Ministry of Munitions on 28 July, 1915, after a series of conferences at the Ministry.[1] The price then fixed was to remain in force until the end of the year, and on the same date further conditions as to the manufacture and testing of the steel were agreed upon.[2]

In the meantime the Ministry was drawing up an amended programme of shell steel manufacture, on which the committee could base its plans.[3] At the end of June the British requirements of shell steel were estimated at 12,000 tons up to 30 September and 50,000 tons in the last quarter of 1915. It was expected that a considerable amount of steel for 9·2-in. shell and other large sizes would be included in the 1915 programme, but a revised programme drawn up in August upset these calculations, as it appeared that steel for the large shell would not be required until 1916. British requirements of shell steel till the end of the year were estimated at 41,000 tons. In September the committee reported that in 1916 British makers of shell steel would be prepared to furnish 24,800 tons weekly, or 1,293,600 tons a year, which, with imports from America, was 57 per cent. more than British and French requirements as then estimated.[4]

This estimate of output depended upon certain alterations being made in the existing specification, which required the use of acid steel and limited the percentage of phosphorus and sulphur to ·05 each. The Steel Makers' Committee had raised this question on 14 August, 1915, and on the proposal being endorsed by the experts at the Ministry, it was brought before the Ordnance Board and the Admiralty.[5] The former agreed on 1 October, 1915, to accept a maximum of ·06 per cent. of phosphorus and ·06 per cent. of sulphur, by which it was reckoned that the output of shell steel could be raised by 25 per cent.[6] In April, 1916, the limit was raised to ·07 per cent. for steel for 6-in. H.E. shells and shells of smaller calibre, if manufactured by the acid open hearth process.[7] The prices of shell steel during 1916 were considered in October, 1915, and were fixed at the existing level.[8]

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[1] Sir L. Llewelyn's Papers, 275. See below, Chapter VI.
[2] *Ibid.*
[3] Sir L. Llewelyn's Papers, 19.
[4] *Ibid.* 275.
[5] *Ibid.*
[6] Hist. Rec./R/1810/7. For further details see Vol. X, Part III.
[7] Sir L. Llewelyn's Papers, 20A.
[8] *Ibid.*, 275.

In 1916 the shell steel estimates for British and French requirements reached the figure of 2,500,000 tons and were not appreciably varied during the year.[1] In November the first programme for 1917 was drawn up, reckoning on an output of 51,000 tons a week. Owing to the submarine menace and the consequent demand for steel for shipbuilding and other requirements, the shell steel programme had to be cut down in February, 1917, to an average of 40,000 tons a week, and again in April to 33,000 tons. In July the shell steel programme was again revised to meet Sir Douglas Haig's minimum demands for shell for issue in France. This involved a reduction in the number of 18-pdr. 4·5-in. and 9·2-in. shells required, and an increase in 6-in. howitzer shell. The net result was an increase of 43,000 tons of steel during the period ending mid-November, 1918, an amount equivalent to 2,400 tons a month. The Iron and Steel Production Department pointed out that if the reduction in 18-pdr. and 4·5-in. shell was made in the Canadian supplies, which was necessary for financial reasons, the new programme would mean a large increase in the demands for steel manufactured in Great Britain; 177,000 tons extra would be required during the period of 18 months, or at the rate of 10,000 tons a month.

Before this programme was adopted, the Government, on the recommendation of a committee which considered the means of providing steel for merchant ships, decided that the manufacture of shell steel for France by British firms and the manufacture of steel for British shell should be diminished as far as was necessary to obtain the steel required for shipbuilding. Works manufacturing both shell steel and ship plates and sections were to give the latter priority.[2] Shell steel for France was to be supplied directly from the United States. Supplies of steel, especially of steel plates, to all Government Departments except the Admiralty, were to be cut down and the export of steel plates to the Allies prohibited.[3] The total home output of shell steel reached the figure of 1,218,191 tons in 1917,[4] while a further 1,180,000 tons were imported from America,[5] making a weekly average of 46,200 tons available during the year to meet the demands of the British Army and the commitments for shell steel for the Allies.

The shell programme for 1918, as originally estimated, involved a demand for 2,500,000 tons of shell steel, of which 1,000,000 tons was to be imported from America. The whole munitions budget, however, had to be revised in December, 1917, in accordance with the recommendations of the Restrictions of Imports Committee. The greatest reduction suffered by the Ministry of Munitions was in Mediterranean

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[1] Sir L. Llewelyn's Papers, 20A.

[2] On 29 July, 1917, the Admiralty and Ministry of Munitions had jointly recommended that ship plates were to have preference over shell steel. It was hoped that 5,000 to 6,000 tons extra of ship plates could be produced weekly (HIST. REC./R/1810/78).

[3] Interim Report by Lord Curzon (3 August, 1917). *See* below, p. 15 and Appendix II.

[4] *Review of Munitions Output*, 1914–18, p. 87 (Copy in HIST. REC./R/1000·1/3).

[5] D.M.R.S. 595.

and Swedish ores, by which the home production of finished steel was estimated to fall from 8½ million tons to 7½ million tons. Shell steel production was not to be diminished, and in the new programme remained unaltered at 1,500,000 tons. The imports of shell steel from America were, however, reduced by half, and owing to the shortage of imported ore there was no possibility of compensating for this by an increased production of British shell steel.[1] In February, 1918, a further reduction in the import of iron ore was necessary, involving a diminution in British shell steel output by 200,000 tons during the year.[2] Actually up to September, 1918, owing to requirements in some directions not having been as great as was anticipated, considerably less shell steel had been used for shell manufacture than had been allocated. When considering the 1919 programme, Mr. Churchill did not see any likelihood of a decrease in the expenditure of gun ammunition taking place, but he thought that reserve stocks of shell might be used during 1919 to avoid reducing issues to the armies. Owing to labour, coal and tonnage shortages, it was obviously impossible to attain the increased production of steel for which the Iron and Steel Department had worked since early in 1916, and the department anticipated that only 1,250,000 tons of shell steel would be produced in 1919. At a meeting of the Co-ordinating Committee, on 20 September, 1918, it was thought that this amount could not be relied upon owing to the shortage of coal and of labour, and two alternative figures were proposed involving further reductions, but the actual allocation on this final steel programme was never fixed.[3]

III.—The Demand for Alloy Steels, High Speed and Carbon Tool Steels.

The control of high speed and carbon tool steel was undertaken by the Ministry of Munitions [4] at the end of 1915, and the supply of these materials to factories in Great Britain and to the Allies was carefully regulated.[5] The organisation of the supply of tool steel was, in February, 1916, undertaken by a Committee of High Speed Steel Manufacturers and Manipulators.[6] The committee distributed orders for this steel, and also allocated supplies of tungsten to the high speed steel manufacturers.[7]

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[1] Memorandum on Munitions Budget in 1918 (D.M.R.S. 595).

[2] Memorandum on Reduced Tonnage for Munitions (D.M.R.S. 595).

[3] D.M.R.S. 595.

[4] The section responsible for this work was originally part of the Raw Materials (later Non-Ferrous Metals) Department, and was not transferred to the Iron and Steel Production Department until the end of 1917.

[5] *Iron and Steel Industry*, 1914–18, p. 15.

[6] The members were: Mr. P. McGregor (chairman), of Messrs. Sanderson Bros. & Newbould; Mr. F. Best, of Messrs. Thomas Firth & Sons; Mr. W. Clark, of Messrs. Vickers, Ltd.; Mr. Senior, of Messrs. Geo. Senior & Sons; Mr. Siddall, of the Sheffield Forge Company.

[7] Sir L. Llewelyn's Papers, 581.

In the following year various experiments were carried out to discover a substitute for Swedish bar iron, on which the tool steel manufacturers were entirely dependent.[1] Relations with Sweden were throughout the war extremely precarious, so that it was desirable to provide, if possible, a British substitute. Some of the leading manufacturers made experiments, under the direction of Mr. Harbord, technical adviser to the department, with "Armco" iron and with specially selected dead soft basic iron. Ingots made with these materials were tested at Sheffield University and compared with steel made from the Swedish iron. Satisfactory results were obtained and increasing quantities of British material were used during the war, although the fears that Swedish material would be absolutely cut off never materialised.[2]

During the first half of 1917 the question of alloy steels became serious owing to the great increase in the aircraft programme.[3] At the end of July, 1917, a conference was held at Sheffield between the Ministry of Munitions, the Air Board and trade representatives to consider how the demand was to be met. It was decided to form an Aircraft Steel Committee at Sheffield under the chairmanship of Mr. Bernard Firth.[4] This committee, together with the existing High Speed Steel Committee, constituted the General Alloy Steel Committee, of which Mr. H. Steel, of Messrs. Steel, Peech and Tozer, was appointed chairman. Estimates of the alloy steel that would be required during the next six months were obtained from the aeroplane and engine makers, and were considered by the committee in conjunction with the departments of the Ministry concerned, orders being placed in accordance with the committee's recommendations. The Alloy Steel Committee also assisted in obtaining increased production.

Difficulties soon arose in the working of this scheme between the various departments of the Ministry, particularly as the control of electric furnaces was divided between several departments. In the autumn of 1917 a sub-committee of the Council Committee on the 1918 programme considered the question of alloy steels from three points of view: departmental organisation, departmental demands and increase of supplies. They recommended the concentration of control under the Iron and Steel Department, and scrutinised and adjusted the requirements of different Departments.[5] The Admiralty put forward a programme for armour piercing shells requiring 7571 tons of finished steel per month, but from evidence before the committee it appeared that at the existing rate of output only 3626 tons a month could be used. A further Admiralty demand for 380 tons of finished

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[1] HIST. REC./R/1810/3.

[2] *Iron and Steel Industry*, 1914–18, p. 16. *See* below, pp. 71-73.

[3] Sir L. Llewelyn's Papers, 581.

[4] The latter appointed the following members of the committee: Mr. Grant, of Messrs. John Brown & Co.; Mr. Kayser, of Messrs. Kayser, Ellison & Co.; Mr. F. Osborn, of Messrs. Sam. Osborn & Co.; Mr. W. Clark (or another representative), of Messrs. Vickers, Ltd. (Sir L. Llewelyn's Papers 581).

[5] M.C. 99, 133, 202, 457; HIST. REC./R/1810/29.

alloy steel for the armament of merchant ships was received, but the committee recommended the use of carbon steel, as in the case of land service guns. Again, the Mechanical Warfare Department demanded 2,400 tons of alloy chrome steel a month, but the committee recommended that 700 tons for armoured plates should be made from nickel steel. Steps were to be taken to induce several firms making high speed steel to execute orders for alloy steel, and stocks of ferro-chrome and ferro-vanadium were to be increased by purchases for the Ministry account.[1] By these means it was expected to meet the demands of the Air Board, Mechanical Warfare Department and the Admiralty.

During the war there was a growing demand for nickel steel and nickel chrome steel, which were used in the manufacture of armour plate, gun forgings, ball bearings, and in aeroplane and submarine work, the largest producers being the armament firms. Considerable quantities of this steel were exported to Australia, France, Russia, Italy, Belgium and Japan, and the fact that its export to Scandinavia was prohibited caused difficulty with Norwegian steel makers who supplied special steels for aeroplane work. A minor point in connection with this steel was the difficulty caused by considerable accumulations of scrap at makers' works, which they were unwilling to sell at the price of ordinary scrap, while its valuable nickel and chrome contents could only be recovered in electric furnaces.[2]

IV.—Forgings, Castings and Stampings.

The control of forgings, castings and stampings was given in September, 1915, to a section of the Machine Tool Department.[3] In June, 1916, a conference was held to consider the supply of forgings for shells, as the new arrangements made had not matured as soon as had been expected, while some manufacturers, who had contracts to supply forgings for the Ministry of Munitions to distribute, were short of steel.[4] The position was serious with regard to 8-in. and 15-in. forgings ; a large number of 8-in. forgings were expected from America, but only 450 were likely to arrive in the near future. The head of the Shell Manufacture Department was anxious to create a stock of 2,000 15-in. forgings ; the Ministry of Munitions had 900 in stock, but no firm was able to machine the extra forgings required. The position as to other sizes was fairly satisfactory.[5] The shortage, however, continued throughout 1917, and in November the Council Sub-Committee on Alloy Steel recommended the transfer of the Forgings and Stampings Section to the Iron & Steel Department.[6] This was accomplished early in 1918, and a main committee was

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[1] Hist. Rec./R/1810/29.
[2] C.I.S.P./Gen./257, 323.
[3] *Iron and Steel Industry*, 1914–18, p. 115.
[4] Hist. Rec./R/1810/72.
[5] *Ibid.*
[6] M.C. 99.

formed, consisting of Mr. D. M. Anderson (Controller of Forgings, Castings and Stampings), Colonel R. Horne, of the Admiralty, Colonel Wright and Mr. W. J. Jones, of the Iron and Steel Department. A committee was also formed consisting of representatives of the departments of the Admiralty and Ministry of Munitions directly concerned in the allocation of forgings, etc., while an outside committee, representing all the forging firms in Great Britain, was constituted to act in an advisory capacity.[1] Similar procedure was adopted in the case of drop-stampings, the inter-departmental committee consisting of representatives from the Air Ministry and the Ministry of Munitions, working with trade representatives of the drop-stamping firms. These arrangements were in satisfactory working order in March, 1918, and steel castings were dealt with in the same way.[2] Considerable improvement in meeting demands for these forgings and castings resulted from this re-organisation, but supply could not be adequate until capacity for their manufacture was increased. Before the war, heavy forgings had been largely imported from Germany, and as the total capacity for castings was unequal to the demand, the shortage could not be overcome until both existing plant had been modernised and new plant installed.[3]

V.—Steel and Iron Tubes.

At the close of 1915, the shortage of steel tubes became suddenly acute owing to the requirements of the Trench Warfare Supply Department, and an inter-departmental conference was held on 1 November, 1915, to consider the situation. The output of the tube works, which were already fully employed, was then at the rate of 34,000 tons per annum. This only covered the requirements of the Admiralty, estimated at 21,840 tons a year, and of the railways, estimated at 9,500 tons.[4] The Trench Warfare Supply Department asked for 13,520 tons of small size solid drawn tubes (October 1915), but this could only be met by cutting down other requirements. It was reported that by additions to plant at the tube works and by the increase of working hours, output could be raised to 51,450 tons per annum.[5] The Admiralty, as the chief user of tubes, wished to take over the control of tube making, but a compromise was effected by the formation, on 1 January, 1916, of a section of the Raw Materials Department, under Eng.-Cdr. Richards, who undertook all work in connection with iron and steel tubes for the Ministry of Munitions, in addition to his work of inspection and allocation of output for the Admiralty.[6]

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[1] M.C. 133, C.I.S.P./Dep/35A.

[2] C.I.S.P./Dep/35A.

[3] *Iron and Steel Industry*, 1914–18, pp. 115–118.

[4] The railways also required from 3,000 to 4,000 tons of lap-welded tubes.

[5] HIST. REC./R/1810/77.

[6] HIST. REC./R/1810/19.

Hitherto, the requirements of other services, besides the Admiralty and railways, had been met without great difficulty at the expense of reducing the manufacturers' stocks. The new section immediately put in hand extensions to plant at various tube works, works which had been closed were re-opened, and the establishment of a new company was sanctioned by the Treasury. The work for different services was allocated to different manufacturers; thus one firm was entirely engaged on aeroplane tubes; another firm undertook supplies for the French Navy, and a third firm supplies for Italy. Steam pipes for the Russian Admiralty were also manufactured in England. The section also made efforts to recover some of the large number of men who had joined the Army in the early stages of the war. Later, arrangements were made for dilution of labour, and, throughout, the staff of the section kept in very close touch with the different works. At any sign of labour unrest, meetings were held at the works, or representatives of the men were separately interviewed, with the satisfactory result that no strike at any of the tube works took place during the war. The section also took steps to make the industry self-supporting as to raw materials by substituting British-made steel for the Swedish billets hitherto used for high grade tubes, while the iron puddlers increased their output of iron, so as to replace the strip for welded tubes formerly obtained from America. Wherever possible, the use of welded tubes was enforced to economise in the use of steel, and in this the department was supported by the French authorities.[1] These efforts were so successful that the average yearly output of tubes of all kinds during the war amounted to 316,700 tons or 235,000,000 ft.

At the time of the Armistice, the chief demands of different Departments were:—

Admiralty	20,800,000 ft. per annum
Merchant Shipping ..	4,500,000 ,, ,, ,,
British Railways ..	108,000,000 ,, ,, ,,
Allies	24,000,000 ,, ,, ,,
Aeroplanes	48,000,000 ,, ,, ,,

The chief difficulty of the section was to meet "spot" demands of new departments and demands for new engines of war. A sudden increase in aeroplane tubes was needed in the autumn of 1917 and the requirements under this head increased by 300 per cent. during the following 12 months. Another example of sudden calls on resources was a demand by the Chief Mechanical Engineer at the War Office for 19,300 miles of water pipes of different sizes.[2]

VI.—Constructional Steel.

The success of the Ministry of Munitions in placing contracts for shell steel immediately produced a shortage of all other kinds of steel. This shortage was realised as early as 1915, and steps were taken for the construction of extensions of the steel works, but before these

[1] HIST. REC./R/1810/19. [2] HIST. REC./R/1810/62.

could come into operation something like a steel famine arose.[1] At the end of 1915 a special section of the Iron and Steel Department was formed, under Mr. John Hall, to supervise the supply of steel for constructional and sectional work. This section dealt with supplies for the erection of new munition factories, and allocated the necessary steel for factory construction to the Admiralty, to ship building firms and to the trade generally. It was found to be difficult to confine the work of this section to constructional steel, however, as at first intended, and it gradually dealt with billets, plates, and all miscellaneous requirements, excepting the Admiralty requirements.[2]

VII.—Conflicting Demands for Steel.

Conflicting demands for steel led gradually to the evolution of machinery for allocating steel among the various competitors for it, in accordance with definite tonnage and steel programmes. But this machinery was not completed until the later years of the war.

From the outset, the Ministry of Munitions tried to work in co-ordination with the Admiralty, and, in July, 1915, asked for a list of the firms supplying steel to the Admiralty or the chief Admiralty contractors, as well as particulars of any large orders.[3] A list of Admiralty needs till the end of 1916 was also obtained, and it was hoped to adjust the requirements of the two Departments.[4] Continual complaints were made by the Admiralty during the autumn of 1915[5] that work on their shipbuilding programme was delayed owing to the orders of the Ministry of Munitions. The difficulty really lay in the shortage of steel, but the Admiralty, with its established position as one of the chief users of steel in the country and its strong local organisation, was not prepared to consent to the complete control of steel passing into the hands of the Ministry.

Negotiations with the Admiralty were carried on in November and December, 1915, in the hope of finding some arrangement by which the continual competition between the Admiralty, Board of Trade and Ministry of Munitions in placing orders might be prevented.[6] A scheme, presented by the Ministry of Munitions on 30 December, 1915, proposed that each steel manufacturer should account to the Ministry of Munitions for the whole of his output week by week, and, having submitted rolling programmes for approval, the whole capacity of the works should be allocated by the Ministry to meet the various demands. The Admiralty and their contractors would place their orders with the manufacturers in precisely the same way as in the past.[7] This scheme was not accepted, and in January, 1916, Mr.

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[1] Sir L. Llewelyn's Papers, 235.
[2] C.R. 4506.
[3] Sir L. Llewelyn's Papers, 275.
[4] *Ibid.*, 235.
[5] *Ibid.*; C.R. 4506.
[6] Sir L. Llewelyn's Papers, 235.
[7] C.R. 4506.

Lloyd George, as Minister of Munitions, agreed that the Admiralty was to have first place for their steel requirements, after the demand for shell steel had been satisfied.[1] Shortly afterwards a working agreement was made between the two Departments, but never put into writing, by which the Admiralty superintendents in the various steel producing districts made up the rolling programmes at the different works for all three Departments, the Admiralty, Ministry and Board of Trade. A further simplification was attained soon afterwards, when the Admiralty became responsible for the steel for merchant shipbuilding, instead of the Board of Trade.[2] The Ministry of Munitions appointed a technical representative in the three centres, Glasgow, Middlesbrough and the Midlands (including South Wales), to consult with the Admiralty superintendent about adjustments of the rolling programme, so as to minimise any loss of output from too frequent changes.[3]

The whole output of steel was not controlled until the end of the year, when by agreement with the Priority Branch, a general order, "The Control of Steel Supplies," was issued on 20 November, 1916, prohibiting the purchase of steel unless a priority certificate had been issued.[4] The Iron and Steel Department also obtained returns of all steel deliveries, thus enabling them to check the use of the priority certificate.[5] The policy of the Ministry in its control of steel remained one of extreme centralisation. The local district organisations, planned by the steel-makers' committee, had not developed, although the committee itself continued to advise the Ministry during the first year of its existence.

Synchronising with the formation of the Iron and Steel Department, a new scheme for the control of the rolling mills was issued on 4 August, 1916. Owners of rolling mills were informed that no order for steel was to be entered on their rolling programme until the purpose for which the steel was intended had been approved. The ordering firm had to quote evidence of approval, which consisted of either (1) Admiralty contract reference and number, (2) War Office contract reference and number, (3) Marine Department of the Board of Trade permit reference and number, declaring that merchant shipping was munition work, (4) Ministry of Munitions contract and reference number, (5) Commission Internationale de Ravitaillement or Commission Française sanction, reference and number, or (6) Ministry of Munitions permit, reference and number, priority classification and purpose. These orders were carried out in the following order of priority: shell, Admiralty, priority instructions 1, 2, 3 and 4, including class A certificates in hand at date of issue of circular, priority instructions 5, class B certificates, priority instructions 6, and class C certificates. No steel, except shell discard quality

[1] C.I.S.P./Dep./5.
[2] *Ibid.*
[3] C.R. 4506.
[4] *Control of Steel Supplies Order*, 20 November 1916.
[5] *Iron and Steel Industry*, 1914–18, p. 14.

was to be rolled for orders ranking below class B certificates. The firms had to send in their weekly rolling programme on a special form to the Ministry for approval or readjustment.[1] Within two months, this scheme resulted in a saving of about 10,000 tons of steel per week from non-essential uses, but this amount was entirely swallowed up by shipping demands.[2]

The priority granted to the Admiralty for all its requirements, without consideration of their relative importance, resulted in a shortage for necessary War Office and munitions work, and steel could only be obtained in doles granted by the Admiralty. The lack of steel for steel works and other extensions was particularly serious.[3] In October, 1916, representations were made to the Admiralty to remedy this state of affairs, and a small consultative committee was formed representing the Works and Shipbuilding Departments of the Admiralty, the War Office, the Ministry of Munitions and the Board of Trade.[4]

At the end of the year, steel for merchant shipbuilding became of imperative importance, and with the formation of the Ministry of Shipping, arrangements were made for close co-ordination with the Ministry of Munitions.[5] In April, 1917, by the reduction of the shell steel programme, about 2,500 tons of steel per week were liberated and transferred to be rolled into ship plates and sections. The merchant shipping programme was twice increased during the summer of 1917.[6] Joint representations were made by the Admiralty and the Ministry of Munitions as to the need for increasing the output of ship plates by sending more steel to the plate mills and decreasing shell steel output (29 July, 1917), and a committee under Lord Curzon sat to consider how material was to be obtained for building 3,100,000 tons of mercantile shipping a year.[7] On 9 August, 1917, the War Cabinet considered the committee's report and decided on the steps to be taken. It was arranged that shell steel for France manufactured by British firms (which amounted to about 10,000 tons a week) was, as far as possible, to be replaced by shell steel from America ; the steel obtained in this way, and also by a reduction in the output of British shell, was to be appropriated for shipbuilding, and absolute priority was to be given to ship plates and sections over all other classes of steel. During six weeks, other Government Departments had their requirements of plates of over $\frac{1}{4}$-in. cut down, while supplies of steel plates for Italian shipbuilding were to be suspended for the same period. Priority was to be given to the extensions of existing plate mills, which were

[1] C.R. 4506.
[2] C.R. 4508.
[3] C. R. 4508.
[4] C.R. 4508 ; C.I.S.P./Dep./5.
[5] CR.. 4507.
[6] C.I.S.P./Dep./5.
[7] The report of this Committee is printed in Appendix II.

then in progress, and the construction of new mills was to be sanctioned and pushed forward.[1] There was considerable difficulty in carrying out these decisions, as it left all important services, except the Admiralty and the steel works extensions, with practically no steel plates of sizes above $\frac{3}{16}$ in. The Advisory Committee of the Ministry of Munitions considered the question in August, the problem they were faced with being the provision of 53,144 tons instead of 30,000 tons of plates and sections per week for the Admiralty.[2] It was found, however, that this amount was far above the existing capacity of the rolling mills; the demand was reduced to 15,000 tons a week extra, and in September arrangements were made to reserve 7,000 tons of plates weekly for other services.[3]

The various conferences on the shipping programme revealed certain administrative weaknesses in the Iron and Steel Department. The centralised control exercised by the Ministry did not work well especially in view of the importance of co-ordination with the Admiralty, which had a de-centralised system. In September, 1917, following a recommendation of the Advisory Committee (2 August, 1917), a scheme was drawn up, in which the country was divided into 6 areas, each area being supervised and regulated by a local Area Committee,[4] consisting of a representative of the Admiralty and of the Ministry of Munitions and three representatives of the industry in the area. The services of the Ministry of Munitions representatives, who had acted with the Admiralty surveyors, were no longer needed. A Central Steel Committee was set up, consisting of delegates of the steel makers appointed by the Area Committees, the secretaries of the Area Committees, the Admiralty steel superintendents, a representative of the Priority Department and a representative of the Admiralty. This committee, which met once a month in London under the chairmanship of Colonel Wright, did useful work. It put an end to the dual control of the rolling mills, where, although the Ministry was responsible for the production of raw steel, the Admiralty Overseer controlled the output and general sequence of work in the mills. Though in some areas the Area Committee left the allocation of orders to the Admiralty superintendent, smooth working depended too much on the personal relations between the superintendent and the committee. The Central Committee also made recommendations for improving transport, for standardising the sizes of steel sheets used in shipbuilding, for the rolling of light plates by sheet mills to relieve the rolling mills of some of their work, while it considered the man power scheme. and the interpretation of price questions.[5] A strong inter-departmental committee, consisting of Col. Wright and Mr. W. J. Jones,

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[1] Hist. Rec./R./1810/78.

[2] A.C. 129.

[3] M.C. 70.

[4] An organization of this kind had been recommended in August, 1916, by the committee which reorganised the department. C.R. 4467, 5087.

[5] Minutes of Central Steel Committee 21 September, 1917, to 19 December, 1918. (C.I.S.P.)Gen./501a.

representing the Ministry, and Col. Horne and Mr. Rogers representing the Admiralty, was also formed to settle all matters of major policy and action.[1] This arrangement resulted in a considerable easing of the steel situation.

The new programme of steel requirements for 1918 submitted to the Sub-Committee on Iron and Steel of the Council Committee on the 1918 munitions programme in August 1917 showed monthly requirements of steel, excluding shell steel, estimated as follows :—[2]

	Dec., 1917. Tons per month.	June, 1918. Tons per month.	Dec., 1918. Tons per month.
Admiralty—			
Navy and Merchant Shipbuilding	228,000	228,000	228,000
Ministry of Munitions—			
Agriculture	2,600	2,600	2,600
Aircraft	9,000	11,000	11,000
Electrical Department	800	800	800
Explosives	1,200	1,200	1,200
Guns	27,200	28,200	28,200
Machine tools	10,000	10,000	10,000
Mechanical transport	4,800	4,200	4,800
Mechanical warfare	6,000	8,000	8,000
Railways	40,000	40,000	39,900
Small arms	2,500	2,700	2,700
Steel works extensions	14,300	15,600	16,900
Trench warfare	14,500	14,500	14,500
Allies—			
France	84,200	84,200	84,200
Other Allies	15,900	15,900	15,900
India Office	4,500	4,500	4,500
War Office	45,000	45,000	45,000
General	88,830	88,830	88,830

Reductions in certain directions were recommended by the sub-committee, but before the programme came into force, the extreme shortage of shipping involved drastic reductions, first in December 1917, and again in February, 1918. It appeared that the Admiralty had received in five months 70,000 tons in excess of the minimum amount guaranteed by the Ministry, and at the same time the latter had shared in the expanding output to the extent of 800 tons weekly by arrangement with the Admiralty beyond the 7,000 tons allotted weekly to other services till the end of 1917.[3] The demands for tanks and railways, however, were continually growing, and steel for the former was 1,600 tons in arrears. Evidence was adduced that ship

[1] HIST. REC./R./1810/28.
[2] HIST. REC./R./1810/78.
[3] HIST. REC./R./1810/33.

yards were not able to absorb all the plates supplied and the Ministry asked for a revision of the September agreement. The matter was again pressed in April, 1918, and the Co-ordinating Committee of the Munitions Council recommended that it was an opportune time to discharge other commitments for plates and sections, some 3,000 to 5,000 tons being available weekly. They suggested that 10,000 tons should be reserved for new locomotives for use in the United Kingdom, that the export of 5,000 tons to Italy in exchange for 750 F.I.A.T. aeroplane engines should be allowed, and that part of the steel due for delivery in the latter half of 1918 should be issued to the French Government.[1]

The demands of the different Departments for 1919 were not completely formulated at the time of the Armistice, but a provisional budget for constructional steel and plates based on estimated requirements for the year was drawn up by the Iron and Steel Department and allocated as follows[2] :—

	Tons.
Admiralty	2,000,000
Allies	525,000
Railways	500,000
Tanks	250,000
Aircraft	200,000
War Office	475,000
Tubes	385,000
Wire	360,000
Other items	395,000
Priority	1,050,000

VIII.—The Tonnage Problem.

The measures taken by the Ministry of Munitions ensured a sufficient supply of shell steel during 1916, and it was not till the 1917 submarine campaign, and the consequent decrease in the imports of iron ore, that the shell programme was cut down owing to the shortage of steel. But this large output of shell steel was only attained at the expense of other essential steel supplies, and throughout the last quarter of 1916 the shortage of constructional steel was acute. From that time onwards steel became the dominating factor of munitions programmes. In September, 1917, Mr. Churchill issued a circular to the different steel works emphasising the fact that it was " a steel war," in order to bring home to every man engaged in the iron and steel trades the importance of his work.[3] In the early days of the war men went in

[1] C.I.S.P./Dep./354. HIST. REC./R./1810/78.
[2] D.M.R.S. 595.
[3] Ministry of Munitions Circular, 10 September, 1917 (C.R. 4368).

large numbers to the Army from the iron ore mines, blast furnaces and steel works, and recruiting schemes continually drew away essential men, whose release from the Colours had afterwards to be obtained with much difficulty. The export of steel was also allowed longer than was, perhaps, expedient, so as to preserve our foreign markets. In November, 1915, Mr. Lysaght, the Spelter Adviser to the Ministry, who was frequently consulted on steel problems, drew up a statement of the steel position for 1916. He estimated the home production of steel ingots at 8,000,000 tons and imports from North America and Scandinavia at 860,000 tons, making a total of 8,860,000 tons. Ingots allocated for shell steel amounted to 4,500,000 tons; 2,000,000 tons of steel ingots were exported and the allowance for waste and scrap amounted to 700,000 tons. This left a balance of 1,660,000 tons of steel ingots for all other purposes, but home consumption in 1913, excluding steel for munitions, had amounted to 4,850,997 tons, and there was, therefore, a probable deficit of 3,190,997 tons from which might be deducted 500,000 tons of ingots made from scrap steel. Even if exports could be reduced, munitions and other military and naval demands were increasing rapidly and the Ministry was thus faced with the problem of finding an additional supply of more than 2,500,000 tons of steel ingots. The home output of finished steel was reckoned at 6,250,000 tons and imports at 750,000 tons. Allowing for the export of 1,500,000 tons, an amount based on the figures for the month of December, 1915, the Iron and Steel Department could reckon on only 5,500,000 tons of finished steel during 1916. Early in January, 1916, the requirements for munitions and home needs had been formulated as follows :—

	Tons.	Tons.
Shell steel for British and French Governments ..		2,500,000
Admiralty requirements (excluding shell steel) ..	700,000	
Mercantile Marine	550,000	
War Office	300,000	
Home railways (including rails)	275,000	
French Government miscellaneous	200,000	
Agriculture	100,000	
Upkeep of factories and important home industries..	250,000	
		2,375,000
Ordinary civilian requirements		2,500,000
Total ..		7,375,000

These estimates showed a shortage of 1,875,000 tons, and, at that time, the difficulties of stopping the export trade were felt to be considerable. Apart from trading and monetary considerations, a large proportion of the steel exported consisted of tin plates, plain and corrugated sheets, black plates, etc., and the plants of the firms engaged in this export trade were not easily convertible. In November, Sir Leonard Llewelyn urged that further steel should be imported from America, but the Treasury refused to allow orders to be placed. The position was placed before the Director-General of Munitions Supply, the figures were scrutinised more closely and orders both in the United States of America and in Canada for 450,000 tons of steel were sanctioned on 25 February, 1916.[1] In addition to these overseas supplies the Ministry had to arrange to increase home output by 2,000,000 tons of steel ingots. Their first steps were to arrange for large extensions of steel works, which in their turn necessitated arrangements for increased supplies of home and imported ore, extensions to blast furnaces, increased supplies of coal, coke and all subsidiary materials. Plans were made for increasing the output of steel ingots by 2,500,000 tons. It was expected that an increase of 500,000 tons in the annual rate of output would be attained by the autumn of 1916 and by the spring of 1917 of 1,000,000 tons.[2] This programme was estimated to require an increase of 2,200,000 tons of pig iron or approximately 5,000,000 tons of ore, 5,000,000 tons of coal, including coal and coke, and 1,000,000 tons of limestone.[3] In May, 1916, however, it was realised that this scheme could not be carried out and certain of the steel works extension schemes, which could not come into working order for a considerable time, were postponed until the corresponding increase in pig iron had been attained. In June, 1916, revised estimates were drawn up for the second half of the year, showing a deficit of finished steel of 242,000 tons. Home requirements and exports were placed at half the pre-war figures, exports being limited to the needs of Indian and Colonial railways, and ship-repairing yards and the provision of steel for neutrals who were manufacturing war materials for Great Britain.

The estimates for the following half-year (January to June, 1917) were based on some improvement in output, but the growing demands for mercantile marine shipbuilding intensified the difficulties of the Iron and Steel Department. Requirements were estimated at 3,472,751 tons of finished steel for munitions and shipping, and 2,150,000 tons for agriculture, export to France (excluding shell steel), other civil requirements, taking production at the rate of about 11,250,000 tons of ingot steel per annum. The first figure was the total of the following demands :—

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[1] Sir L. Llewelyn's Papers 134.

[2] Hist. Rec./R./1810/41.

[3] Sir L. Llewelyn's Papers 20A.

	Tons
Shell steel (British)	1,523,600
Shell steel (French)	520,000
Guns and small arms	66,550
Admiralty	330,000
Mercantile marine	310,000
Italian mercantile marine	24,000
Other Allies	26,000
British railways	67,375
Mechanical transport	50,000
Trench warfare	36,116
Military railway, Mesopotamia and Inland Water Transport, etc.	481,720
Tanks	25,000
Aircraft	12,390
Total ..	3,472,751 tons

If the new tank programme which was under discussion was adopted the estimated requirements under this head would be doubled. To meet the demand for 3,472,751 tons the Ministry expected to obtain a total of 3,283,800 tons of finished steel, 390,000 tons of which would come from America. This left a deficit for the half-year of 188,951 tons. A possible readjustment was suggested by reducing the shell steel supplied to France and purchasing the whole of the material for military railways abroad. This would give a surplus of 801,049 tons for the sixth month, which could be applied to other necessary services. The great difficulty at this time was the shortage of labour. Apart from extensions of capacity at the works, another 520,000 tons would have been forthcoming if the necessary labour had been found.[1] The situation was worse at the end of the six months than had been anticipated, and on 17 July, 1917, when an Admiralty demand for an increase in the tonnage of steel allocated for shipping construction from 30,000 tons a week to 53,144 tons was received, the Ministry was faced by a shortage of 103,000 tons per month.[2] Temporarily this was met by a re-arrangement of the allocations to different services, until an increased output of plates from the mills could be obtained.[3] The requirements for 1918 were examined by the Sub-Committee on Iron and Steel during the autumn of 1917, and showed a considerable increase over 1917. For the six months ending 30 June, 1918, an average monthly total of 804,230 tons was demanded by different Departments and for the following six months the average monthly

[1] C.R. 4507.

[2] C.R. 4414.

[3] See below p. 23.

total had risen to 806,030. These totals represented the following departmental demands :—

—	Jan.–June, 1918. Tons per month.		July–Dec., 1918. Tons per month.	
Admiralty—				
Warships, Merchant ships ..	228,000		228,000	
Armament	18,500		18,500	
		246,500		246,500
Ministry of Munitions—				
Agriculture	2,600		2,600	
Aircraft	11,000		11,000	
Electrical Department ..	800		800	
Explosives	1,200		1,200	
Guns	24,200		24,200	
Machine guns	4,000		4,000	
Machine tools	10,000		10,000	
Mechanical transport	4,200		4,800	
Mechanical warfare	8,000		8,000	
Railways	40,000		39,900	
Shell—				
British	104,000		104,000	
France	34,600		34,600	
Other Allies	15,900		15,900	
Shell parts	26,000		26,000	
Small arms	2,700		2,700	
Steel works extensions ..	15,600		16,900	
Trench warfare for aerial bomb programme	14,500		14,500	
		319,300		321,100
Allies (excluding shell steel)—				
France	84,200		84,200	
Other Allies	15,900		15,900	
		100,100		100,100
India Office		4,500		4,500
War Office		45,000		45,000
General—				
Machinery and Plant	8,400		8,400	
Construction	34,000		34,000	
Miscellaneous	46,430		46,430	
		88,830		88,830
Total		804,230		806,030

To meet these demands the estimated supply, based on the import of 550,000 tons of iron ore monthly from Spain, was 696,000 tons a month in the first half year and 721,000 tons a month in the second half year.[1] The discrepancy between demand and supply, however, practically disappeared under the close scrutiny of the sub-committee. In the first place the Admiralty demands were calculated for a large shipbuilding programme, without reference to the capacity of the plate mills, which for another twelve months could not deal with the

[1] Report of Sub-Committee on Iron and Steel Programme, 22 September, 1917 (HIST. REC./R./1810/78.)

quantity required. Consequently a scheme based upon the available output of plates reduced the Admiralty demand to 144,800 tons a month for the first half year and 190,200 for the second half year. Further economies were attained by an agreement under which the shell steel supplied to France was cut down by half in December, 1917, and was to cease altogether during 1918, arrangements being made for the substitution of American shell steel, shipped direct to France.[1] Other supplies to the Allies, excluding shell steel, were reduced to half the amounts demanded. Subsequent events led to the modification of the Admiralty demand, as the capacity of the shipyards rather than the rolling mills became the limiting factor.[2]

Before the revised programme came into operation, however, the whole situation was altered, owing to the drastic limitation of imports necessitated by the shortage of shipping, as a result of the submarine campaign. The 1918 munitions programme had been based on an allocation by the Shipping Controller of tonnage for the import of munitions to the amount of 15,000,000 tons, an increase of 2,500,000 tons over the 1917 allocation. The whole situation was considered by the Cabinet Restrictions of Imports Committee, who cut down the munitions allocation to 11,000,000 tons (31 January, 1918).[3] As a result a drastic cut had to be made in the imports of Spanish and Mediterranean iron ore, and the iron and steel programme was subjected to stringent reductions. The following table shows the effect of this reduction on the iron and steel imports :—

—	Actual imports in 1917.	Allocation of import tonnage asked for in 1918.	Minimum imports required to arrive in Gt. Britain to meet 1918 programme.	Proposed allocation on basis of 11,000,000 tons to arrive in Gt. Britain.
	Tons.	Tons.	Tons.	Tons.
Iron ore	6,535,000	7,622,000	6,660,000	6,060,000
Manganese ore	417,000	576,000	420,000	360,000
Shell steel and forgings ..	1,180,000	1,200,000	1,000,000	500,000
Other iron and steel ..	400,000	396,000	300,000	250,000

This involved a 10 per cent. reduction in the programme and a new steel budget, based on iron ore imports at the rate of 450,000 tons a month from Spain and 55,000 tons from Scandinavia, was drawn up. The shortage could not be met from home ores, although every effort was being made to increase their use, and it appeared that the estimated British production of finished steel in 1918 would be reduced by 1,000,000 tons. The Ministry immediately made arrangements for the purchase of 500,000 tons of shell steel in America for Great Britain in addition to the 500,000 tons already procured for France. The Iron and Steel Production Department

[1] French supplies, however, as will be seen elsewhere, were not entirely cut off, but were continued on a reduced scale.

[2] HIST. REC./R./1810/78. See also below, p. 24.

[3] D.M.R.S. 595.

could thus anticipate a supply of 7,500,000 tons of finished steel, which it was proposed to allocate as follows :—[1]

	Tons
Admiralty	2,000,000
Shell steel (home production) ..	1,500,000
Other munitions	2,200,000
Allies..	200,000
War Office and India Office ..	600,000
Other requirements (tubes, wire, constructional steel, etc., unallocated surplus)	1,000,000
Total ..	7,500,000 tons

In February, 1918, a further restriction of imports was imposed by the Shipping Controller, limiting the monthly ore imports to 400,000 tons from Spain and 50,000 tons from Scandinavia, and the steel budget had to be revised on a basis of only 6,500,000 tons of finished steel to be produced in Great Britain.[2] This meant that Admiralty steel was reduced by 400,000 tons, that home railways, despite their urgent need, would be limited to the same figure as in 1917, that France would have to depend upon America for her shell steel, and would suffer a 50 per cent. cut in hematite pig iron and a 33 per cent. cut in certain steel supplies unobtainable in America, that Italy would have, after six months, to depend upon America for her shell steel. In addition, gun manufacture would be reduced, War Office supplies of steel for railways, field work, etc., would be reduced to 450,000 tons against requirements of 670,000 tons, and there would be little prospect of supplying further steel for the American Expeditionary Force.[3] The consequent reduction in supplies to the Allies and to the different Departments produced many protests,[4] but in practice the situation was eased in the spring of 1918 as the Admiralty were unable to consume their whole allocation for merchant shipbuilding, and the surplus was used to increase supplies to the Allies and for the railways in Great Britain and in France.[5] In the autumn the Ministry obtained priority for munitions shipping tonnage from October, 1918 to March, 1919 over food tonnage,[6] but by this time another difficulty, the shortage of coal, had become formidable. This shortage, due to the recruitment of miners, threatened to be a very serious handicap to steel production, but under the coal scheme for

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[1] Memorandum on Munitions Budget. December, 1917 (D.M.R.S. 595).

[2] D.M.R.S. 595.

[3] Ministry of Munitions to War Office, 4 February, 1918. (D.M.R.S. 595).

[4] D.M.R.S. 434, 595.

[5] HIST. REC./R./1810/78 ; C.I.S.P./Dep./35.A.

[6] D.M.R.S. 595.

rationing industrial coal, evolved in July, 1918, 42,000,000 tons were made available for coke ovens, blast furnaces, iron, steel and metal works and for iron ore mines and limestone quarries, etc. Thus, while schemes for extensions, electrical undertakings, and aircraft construction had to remain in abeyance, the continued output of existing steel and iron works would be secured.[1] In July, when the 1919 programme for iron and steel was discussed by the Co-ordinating Committee, the requirements for the Admiralty, War Office, and Ministry of Munitions were estimated at 6,986,000 tons. Home production was estimated at 7,875,000 tons of finished steel, leaving 889,000 tons for all other purposes. The Statistical Department pointed out that the only steel which would have to be obtained in the United States of America would be certain special steel, amounting to 492,000 tons, for which the capacity in Great Britain was insufficient; if arrangements were made for Italian shell to be purchased in America direct by the Italians, this figure would be reduced to about 264,000 tons.[2] The coal position continued to be very serious and in September, 1918, a reduction of 10 per cent. in the steel to be allowed to both the Admiralty and the Ministry was being discussed in order to economise coal.

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[1] C.I.S.P./Dep./35. A.

[2] HIST. REC./R/1810/78.

CHAPTER II.

THE SUPPLY OF IRON ORE AND PIG IRON.

1.—Imports of Iron Ore.

(*a*) Spanish Ores.

The basis of all the schemes formulated in 1915 and 1916 by the Ministry of Munitions for increasing the output of steel for munitions purposes depended on an adequate supply of foreign ore being maintained, the chief countries of origin being Spain and Sweden. By far the largest imports of ore (about 75 per cent. of the total) consisted of Spanish hematite, which was required by practically all the blast furnaces and steel works which were turned over to shell steel manufacture in the first instance. The chief ore deposits in Spain lay in two groups, the first in the north in the provinces of Viscaya and Santander, the ore being shipped from ports on the Bay of Biscay; the second in the south in the provinces of Almeria and Murcia, the ore being shipped from Mediterranean ports, and in the province of Huelva, shipped from southern Atlantic ports. Although in 1915, the total exports from Spain had dropped 50 per cent. below the 1913 figures, the exports to the United Kingdom showed little falling off, so that with the shutting off of the markets of Central Europe a virtual monopoly was obtained.[1]

In 1914, both prices and freight rates were low,[2] but, though a rise followed the declaration of war, freights being doubled, no great increase in price took place until the end of 1915, owing to the falling off of the demand from Central Europe. Early in January, 1916, however, the price of iron ore reached an abnormally high figure. This was chiefly due to enhanced freight rates, caused by the fact that steamers clearing to West and South France with coal cargoes returned in ballast to the United Kingdom in order to save time, instead of following the pre-war custom of loading for the return voyage a cargo of iron ore either at some Algerian or Moroccan port or in Spain. Freights had risen to 30*s.* per ton, but even at exorbitant rates the Ministry could not obtain adequate tonnage, and the consequent uncertainty made the ironmasters unable to quote fixed prices for their output. In order to meet this difficulty, a scheme for securing importers against increased freights was put forward. The Ministry was to guarantee freights at 17*s.* a ton, while the resultant pig iron was to be sold at a fixed price.[3]

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[1] Hist. Rec./H./1800/1.

[2] Freight rates in 1914 were 4*s.* 6*d.* to 5*s.* 6*d.* a ton from Spain to the United Kingdom.

[3] Hist. Rec./H./1800/1.

At a conference held on 11 February, 1916, between representatives of the Ministry of Munitions, the Bunker Coal Committee, and the Admiralty, on the subject of tonnage, it was suggested that the Ministry should appoint an official broker to charter ships and obtain tonnage and that the ore should be purchased through the merchants then dealing in it, f.o.b., Spanish or Mediterranean ports. If the Government made themselves responsible for freights, a price could be fixed for ore.[1]

This freight scheme was discussed with the representatives of a large firm of iron and steel manufacturers,[2] and with the ore merchants. It was realised that if the scheme was to be successful, it was essential that ample supplies of ore should be secured and contracted for over a period of six to nine months, so as to avoid the possibility of the mine owners putting up their prices directly the Government proposals became known. The British ore merchants were asked to send in returns of the actual amount of ore under contract and the dates when delivery became due and further to assist in placing contracts before the f.o.b. price fixed by the Ministry was known.[3] This scheme materialised with the appointment of Mr. T. Woodward Owen as the official Ore Broker and of a small advisory committee of merchants to assist him in the necessary arrangements. Chartering under the Government freight scheme began on 23 March, 1916. Competition for tonnage amongst the importers being eliminated a considerable drop in freights resulted, though it was not considered politic to reduce rates unduly, for fear of driving neutral ships from the ore trade. Neutral ships were also kept in this trade by the threat of refusing coal bunkers to ships clearing for French and Spanish ports, unless they brought back cargoes of iron ore. British colliers carrying coal at Blue Book rates were also directed into the ore trade for the return voyage.

The price of hematite pig iron was fixed at £6 12*s.* 6*d.* per ton, on the freight basis of 17s. per ton from Bilbao to all discharging ports, the Government taking responsibility for excess freights and demurrage at ports of discharge, arising from circumstances outside the control of the iron masters. The scheme worked well. Freight rates showed a steady decline till the middle of April, 1916, and tonnage was offered freely for ore cargoes. In May the imports of ore from Spain were 600,000 tons, but it was becoming clear that supplies from the Spanish mines depended largely on the receipt of coal from Great Britain.[4]

With a view to maintaining regular tonnage the Ministry in July, 1916, made a return to the Admiralty of the ore required for the following six months, giving the following estimates—from the Mediterranean and South Spanish ports 2,094,939 tons, and from North Spanish ports 1,765,809 tons.[5]

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[1] HIST. REC./H./1800/1.
[2] HIST. REC./R./1810/45.
[3] Sir L. Llewelyn's Papers, 254.
[4] HIST. REC./H./1800/1.
[5] *Ibid.* It was difficult to obtain tonnage for North Spanish ports, where the shelter and loading facilities were poor.

On the formation of the Iron and Steel Department in September, 1916, the Committee of Iron Ore Merchants was dissolved and the control exercised by the Ministry of Munitions over iron ore imports was strengthened. Mr. F. L. MacLeod became official Adviser on Foreign Ore and local committees of iron masters were established in South Wales, Scotland, and in the North West and North East Coast Districts.[1]

In the autumn of 1916 the tonnage problem should have been somewhat eased by the decision of the Italian Government to authorise an arrangement by which Italian ships carrying coal from Great Britain should call for ore cargoes on the return voyage, 23 ships being released in November, 1916, for the Mediterranean ore trade. The French Government also arranged for some of their ships to return with ore cargoes, to the amount of 15,000 tons a month. These arrangements did not bring the expected increase in ore tonnage owing to the growing severity of the submarine campaign. This was especially felt in the voyage from the North Spanish ports. Neutral shipowners were reluctant to risk their ships, even if the crews could be obtained. The Ministry of Munitions therefore proposed a scheme for the insurance of neutral tonnage, which in January, 1917, was sanctioned by the Treasury. Under this scheme a rebate or bounty was to be granted to neutral shipowners, calculated either at a rate per ton of freight or at a rate upon the value of the hull and cargo, not exceeding the difference between the market rates obtaining for insurance against war risks and rates obtaining before the rise of freights in October, 1916. The scheme however came to nothing, owing to the market rate for war risk insurance or neutral tonnage having considerably increased with the submarine menace.[2]

Besides the tonnage problem, labour troubles in Spain and German intrigues to obtain control of ore mines and of railways interfered to some extent with the output of ore.[3] In June, 1917, the situation was so serious that the Iron and Steel Production Department made special representations to the Minister showing that, while requirements for hematite ore were steadily increasing, monthly imports showed a decided decrease. In the first six months of 1917 only 3,141,912 tons of ore had been shipped, as against 3,389,580 in the same period of the previous years. The monthly figures were as follow :—

	1916.	1917.
January	526,269	511,804
February	403,973	507,560
March	554,379	494,188
April	571,659	522,289
May	687,742	626,625
June	645,559	479,446

[1] *Iron and Steel Industry*, 1914–1918. pp. 89 ff.
[2] *Ibid.* M.F./Gen./228.
[3] HIST. REC./H./1800/1.

The decrease in the summer months was particularly serious as the greater part of the ore imports were usually shipped during the more favourable season.[1]

The situation was considered by the Committee on Increased Merchant Shipbuilding in July. It was reported that 200,000 tons of ore were lying awaiting shipment at Bilbao. The Shipping Controller pointed out that the position was due to the sinking of ore ships, which had resulted in a loss of 229,800 tons, an amount nearly equal to the total shortage in the first half of 1917.[2] He stated that all ore had been lifted from Spain, except some 50,000 tons which were lying at ports with open anchorages and therefore peculiarly exposed to the submarine danger. He hoped that in the following month 550,000 tons of ore would be imported, but Sir L. Worthington Evans pointed out that this was much less than was expected during the summer months.

In August, 1917, M. Loucheur, of the French Ministry of Munitions, presented a scheme for withdrawing ore traffic from the Mediterranean ports, and concentrating on the Bay ports. If this scheme were accepted British and Danish ships engaged in the coal trade to Italy would be diverted to the ore traffic from the Bay, and coal would be supplied to Italy from the mines in South East France by rail. The provision of the necessary railway transport was however found to be impossible and an alternative scheme was adopted in September, 1917. English coals were put into Blaye, a port on the Garonne below Bordeaux, and then railed to Italy or carried into Italy by means of short sea trips from a French port. The homeward-bound coal ships then picked up ore at North Spanish ports.[3]

Meanwhile the situation at home was becoming very critical. At the beginning of the year 128 hematite furnaces had been operating, but in August, 13 had been put out of blast and a further decrease was threatened owing to the ore shortage.[4] The monthly arrivals of ore did not even reach the 550,000 tons expected by the Ministry of Shipping, and a Council Sub-Committee on the Importation of Iron Ore met to consider the situation on 17 September, 1917. The Shipping Controller agreed to endeavour to carry 600,000 tons a month from Spanish and Mediterranean ports, but was unable definitely to promise this amount. The French scheme was discussed and a project for building concrete towing barges for bringing ore from Spain was brought forward.[5] This plan had to be given up as the Shipping Controller said that towing in the Bay was impossible, but he was prepared to arrange for towing coal across the Channel and so release more shipping for the ore traffic.[6] In November a further difficulty arose as the Italian Government diverted a large amount of shipping from the ore to the grain trade.[7] The official Ore Broker on 14 December estimated that the arrears on contracts for Spanish ore

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[1] C.R. 4368.
[2] C.R. 4414.
[3] HIST. REC./H./1800/1.
[4] M.C. 65.
[5] M.C. 72.
[6] HIST. REC./R./1810/25. M.C. 72.
[7] HIST. REC./H./1800/1.

would amount at the end of the year to 800,000 tons, of which between 500,000 and 600,000 tons would represent the proportion awaiting shipment in North Spanish ports. Charterings from the Mediterranean had also fallen off.[1]

The Shipping Controller was urged to increase the allocation of tonnage for the shipment of this ore (September, 1917), but he was unable to do so, and in November, had to propose a reduction.[2] Mr. Churchill deprecated this. The progressive reduction had created a very serious situation, stocks were very low, and, if a minimum monthly importation of 500,000 tons was not secured, the shipbuilding and munitions programmes sanctioned by the War Cabinet could not be carried out. The situation was still difficult in February, 1918, but it improved soon afterwards, and a proposed diversion of traffic from East Coast to West Coast ports was not carried out.[3]

The continual increase in the outward coal freights to Spain, which, ruling at about 6*s.* per ton before the war, rose during 1917 from 70*s.* to 300*s.*, and the consequent rise in the price of coal had very serious effects on the production of ore in Spain, as it not only affected the mines themselves, but also the cost of railway transport between the mining districts and the coast. Mr. MacLeod urged that 1,800,000 tons of British coal, needed by Spain for her industries and railways should be shipped at a freight of 30*s.* a ton; this would relieve the situation all over Spain and ensure the production of ore vital to the British and Allied cause. The Shipping Controller, however, refused to take any steps to reduce freights for fear of driving away Spanish tonnage, which was then transporting nearly all the coal imported by Spain. The policy of the Ministry of Shipping was to attract Spanish ships into the coal trade by the high freights earned, as, otherwise, they went into services out of the submarine zone, where they were of no use to the Allied cause. For this reason it was recommended that no charters to Spain should be allowed except at the full Spanish freight rates, whether the ship to be chartered was British or neutral. Allied dependence on Spanish exports prevented any pressure being brought on the Spanish shipowners, but it was hoped in this way to bribe them to keep their ships in a dangerous trade.

At the beginning of 1918 the effect of this policy began to be felt. The Great Southern Railway Company of Spain[4] asked for a bonus of 3*s.* 6*d.* on every ton of ore carried over their system for shipment to the United Kingdom in order to compensate them for the rise in coal prices. They claimed that without financial assistance the ore traffic would be carried on at a loss and shortly afterwards the company refused to carry ore altogether. Other companies threatened to pursue the same course. The question was discussed in the early months of

[1] M.C. 349. [2] M.C. 65, 72, 84. [3] C.R.V./Gen./1611.

[4] A controlling interest in the Southern Spain Railway had been acquired, not by a British syndicate, as advised by the British Ambassador in Madrid, but by the Andalusian Company of Paris, which was partly British (September, 1916). C.R.V./S./09, 040. HIST. REC./H./1800/1.

1918, and a conference was held on 17 April in an attempt to reconcile the views of the different Departments. No agreement was reached, as the Shipping Controller maintained that the high freight policy was necessary in face of the desperate shortage of tonnage. The Ministry of Munitions, however, doubted if any considerable number of Spanish ships had been attracted into the trade, while freights were still rising and the ore supplies showed no increase. They wished for the whole situation to be reviewed by the War Cabinet and urged that the embargo on the chartering of controlled neutral ships to Spanish ports should be raised. While they suggested that the lead and pyrites mines should be rationed and coal supplied to them in controlled ships, it was realised that it was impossible to ration the iron mines In a rough estimate of the requirements of the latter, the amount was given at 10,000 tons, but it was impossible to separate the proportion of coal used by the railway companies in the iron ore traffic from that used for other classes of goods.[1]

While the freight question was under discussion, the Foreign Office was engaged in negotiating a commercial agreement with the Spanish Government, which, early in 1917, had issued a Royal Order to the effect that vessels loading with iron ore must on their return journey bring back coal to the amount of 150,000 tons a month. This had immediately produced great shipping delays and the Spanish Government in March, 1917, sent over the Marquis of Cortina to negotiate an agreement. Mr. MacLeod took part in the negotiations that followed, but before the Cortina agreement was signed the Spanish Government fell, and the new Government started fresh negotiations, which finally resulted in an agreement signed on 29 May, 1918. As a result, the chief difficulties in the supply of Spanish iron ore were removed during the closing months of the war.[2]

Manganiferous iron ore, used in the manufacture of spiegel-eisen, was also obtained largely from Southern Spain as well as from Algeria and Greece. This ore, containing less than 30 per cent. of manganese, was imported in the following quantities :—

	1913.	1914.	1915.	1916.[3]
	Tons.	Tons.	Tons.	Tons.
Algeria	3,797	16,857	30,334	—
Spain	188,196	120,249	83,639	47,137
Greece	13,499	17,859	17,986	34,855
Other foreign countries	6,152	7,911	1,289	—
British Indies	—	2,717	5,720	—
Total	211,644	165,593	138,968	81,992

The drop in imports was to some extent met by the development of the production of British manganiferous ores.

[1] HIST. REC./R./1810/66 ; C.R.V./F./139.

[2] C.R.V./S./0432, 0545 ; HIST. REC./R./1810/66 ; *Iron and Steel Industry*, 1914–18, pp. 90, 91.

[3] C.R. 4368.

(*b*) Scandinavian Ores.

The second most important source of foreign iron ore was Scandinavia. Swedish ore was especially important as an oxidising agent in the manufacture of open-hearth basic steel, and was exceedingly difficult to replace. Apart from the shipping difficulties, the uncertainty of our political relations with Sweden during the war made this dependence on Swedish ore a source of grave anxiety to the Ministry.

The question of the cutting off of Swedish supplies was considered as early as August, 1915,[1] but in a more detailed manner in the following January, when the Ministry reported that although substitutes could be found, substitution could only be effected at the expense of the steel output, the shortage of steel at that date being some 2,000,000 tons per annum.[2] In the following May, a sub-committee was appointed to consider the possibility of making Great Britain independent of foreign countries for supplies of iron and steel. The Ministry of Munitions stated that during 1916 contracts for 600,000 tons of Swedish iron ore had been placed. No known deposit of ore could be used as a complete substitute, the special features of Swedish ore being a low percentage of silica, a high percentage of iron, and exceptionally good mechanical conditions. Ores from Brazil, South Australia, Bengal, Morocco, Spitzbergen, and Spain were suggested as substitutes, and it was decided to carry on investigations with these ores, but there was no prospect of their being available to meet the immediate situation.[3]

Further conferences were held at the Foreign Office and on 18 May, 1916, it was decided to increase the quantities of ore coming from Sweden as soon as possible. The Government was not to appear in the negotiations, which were to be carried through by two British firms. One of these firms, which had a long contract for 750,000 tons of Swedish ore, with a clause giving them an option of requiring an increase of delivery by 33 per cent, agreed to anticipate deliveries to the extent of 100,000 tons. The second firm made enquiries for 100,000 tons, the price to be fixed c.i.f. if possible; if the shippers of the ore could not find the necessary tonnage, the British Government would do so. Negotiations were also made through other firms for buying up to 500,000 tons of Swedish ore. The Ministry of Munitions had information that over 1,500,000 tons of ore were lying at Narvik, awaiting shipment, some of it being for America, and, owing to the importance of getting hold of this supply, the Admiralty gave orders that this ore was to have tonnage preference over other Scandinavian goods[4] and the imports from Narvik showed a satisfactory increase, the amounts being:—April 35,000 tons, May 51,000 tons and June 73,000 tons.[5]

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[1] C.R. 1890.
[2] Sir L. Llewelyn's Papers, 288.
[3] *Ibid.* 367.
[4] Sir L. Llewelyn's Papers, 367. Hist. Rec./H./1810/2.
[5] Sir L. Llewelyn's Papers, 367.

On 13 November, 1916, the selling agents of the firm which owned the Gellivare and Kuruanavarra iron ore fields, entered into an agreement with the Ministry of Munitions to supply during 1917, 500,000 tons, to be increased at option to 1,000,000 tons, of iron ore. The price originally asked by the company was 21*s.* per ton f.o.b. Narvik for D & G grades, 19*s.* for C.2 grade and 22*s.* for C.1 grade, but after negotiations the Ministry obtained a reduction for D & G grades to 18*s.* per ton. The contracts already made with seven British steel and iron companies were to be carried out on the same method as hitherto.[1] This secured to the steel industry the necessary supplies of high-grade ore, but shipping difficulties increased throughout 1917 and no less than 237,000 tons of ore were lost through submarine warfare in the first six months of the year.[2] In June the Ministry exercised the option of increasing the amount of the ore purchased through the agents to 1,000,000 tons.[3] The sinkings of ore ships continued, but on 22 September, 1917, the stock of Swedish ore in the country was 360,000 tons, or sufficient for seven months. There was also a stock of 1,000,000 tons at Narvik,[4] and during 1918 the shipments from this port increased and in March about 40,000 tons a month were arriving.[5]

On 6 February, 1918, a conference was held at the Foreign Office to discuss the Swedish iron ore position. It was attended by representatives of the Treasury, Foreign Office and Ministry of Munitions, together with delegates from the United States of America, France, Italy and Sweden. Before the war nearly 80 per cent. of the Swedish exports of iron ore had gone to Germany, but the dependence of Great Britain and her Allies on Swedish exports had made it difficult for the Foreign Office to bring any pressure to bear on the Swedish Government to cut off the supply to Germany by refusing to export coal from Great Britain. No agreement was reached at this conference, but negotiations were not broken off and on 29 May, 1918, an agreement was concluded with the Swedish Government, the guiding principle of which was the equal division of the iron ore exports between the Allied and Associated Governments and Germany. The Swedish Government undertook that exports of Swedish ore from 1 July, 1918, should not exceed 6,000,000 tons per annum, and that of such exports the quantity exported to the Central Powers and their Allies was not to exceed 3,500,000 tons. The proportion of the different grades of ore were also fixed. The Allied and Associated Governments undertook to purchase 2,000,000 tons of ore from the Gellivare ore fields in the year following 1 July, 1918, with the right to purchase a further 500,000 tons from any source in Sweden.[6] None of this ore had been delivered at the time of the Armistice, but part payment had been made by the Ministry of Munitions.[7]

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[1] HIST. REC./H./1810/2; *Iron and Steel Industry*, 1914–18, p. 91.
[2] HIST. REC./H./1810/2.
[3] *Ibid.*
[4] HIST. REC./R./1810/47.
[5] HIST. REC./H./1810/2.
[6] *Ibid.*
[7] HIST. REC./R./1812/1.

Most of the ore exported from Norway (for which contracts for 400,000 tons had been made in 1916), really consisted of Swedish ore shipped from Norwegian ports.[1] The only important export of ferrous metal of Norwegian origin was in the form of briquettes and concentrates from the Sydvaranger Mine. These briquettes were of special importance as they had a very low percentage of sulphur and phosphorus (·012 in each case) and could be used as substitutes for Swedish iron ore. In consequence, in the summer of 1916, besides the arrangements for increasing the stock of Swedish ore, the Ministry entered into negotiations to buy 100,000 tons of Sydvaranger briquettes and approached the Coal Exports Committee to supply the mines with the coal necessary for the briquetting process.[2] Before this there had been a considerable correspondence between the company's British agent and the Foreign Office (May, 1915, onwards), while the Sydvaranger Company had approached the Danish Foreign Office, with a view to the export of briquettes to England in return for coal supplies. The matter was complicated by the fact that the company was under German control and was a large exporter of briquettes and concentrates to Germany, where they were of special value for shell steel production, which the Foreign Office was anxious to curtail.

On 14 April, 1917, a new contract was entered into between the Ministry and the Sydvaranger Company for the supply of about 24,000 tons of briquettes, with a ·002% phosphorus maximum at 30 kr. a ton delivered f.o.b., Kirkenaes, in return for a guarantee that coal would be delivered to the company at the basis price of 30*s*. a ton c.i.f., Kirkenaes.[3] In June, when this contract had been filled the company closed down its briquette plant, while continuing its export of concentrates to Germany. In order to bring pressure to bear on the company it was placed on the "Black List" (22 November, 1917), with the result that it accepted a contract for another 30,000 tons of briquettes, and offered to curtail its trade with Germany if supplies of coal and wearing parts for machinery could be supplied from Great Britain.

(*c*) MANGANESE ORES.

Manganese ore, containing not less than 45 per cent. of manganese, which was used for manufacturing ferro-manganese, was imported in 1914, from the following countries:—47 per cent. from India, 37 per cent. from Russia, 10 per cent. from Brazil and 6 per cent. from other countries. During the first years of the war, supplies came almost entirely fron India. In 1917, however, shipments from Sekondi, on the West Coast of Africa, began and by August, 1918, formed 15

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[1] Sir L. Llewelyn's Papers, 367.

[2] Sir L. Llewelyn's Papers, 367.

[3] For a more detailed account of these negotiations, *see* HIST. REC./H./1810/2; see also Vol. VII, Part I.

per cent. of the total imports of manganese ore.[1] The total imports of this ore during the war were :—in 1914, 479,435 tons ; in 1915, 372,724 tons ; in 1916, 440,659 tons ; in 1917, 331,264 tons ; and in 1918, 365,606 tons.[2] The decline in imports in 1917 produced a very serious situation ; the normal monthly import was 45,000 tons, but in four months—March, to June—only 83,175 tons arrived and in June only 12,650 tons. The resulting drop in the output of ferro-manganese, affected not only the steel production in Great Britain, but also in Italy, France, the United States and Canada, which depended to a large extent on this country for their supplies of ferro-manganese.[3] The Shipping Controller was urged to increase the allocation of tonnage for the shipment of this ore, and during 1918 the position improved.

II.—Development of Home Ore Production.

The iron ore production of Great Britain was not at first a vital factor in the production of steel for munitions. The majority of the steel furnaces in the country were built for the acid process and depended on the use of hematite ore, of which the greater part had to be imported, for the production of steel containing a low percentage of phosphorus and sulphur. The ironfields of Cumberland and Lancashire produced hematite ore and a very small amount was obtained in Wales and the Forest of Dean,[4] but the great mass of British iron ore was not used for steel making, but for forge and foundry iron.

When the submarine campaign during 1916 made the import of foreign ore precarious and it appeared that the increasing demands for steel could not be met from the supplies of hematite ore, the Ministry of Munitions inaugurated a scheme for developing the production of home ores to meet the needs of the basic furnaces, which were to provide munitions steel by the basic process. Reports were made by Mr. Frank Merricks on certain ironstone quarries and on his recommendation they were taken over by the Ministry of Munitions, the labour being provided by German prisoners of war. By the end of December, 1916, camps had been erected and about 1,500 prisoners were working in these quarries and also in limestone quarries. A more complete survey of the resources of the country was made during the autumn of 1916 ; Mr. G. E. Stephenson examined the iron deposits in the Midlands and the Cleveland district, and reported that if labour could be found the supplies of material were practically unlimited.

On 23 February, 1917, Sir John Hunter was asked to undertake the organisation of home ore production and of the supply of steel

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[1] *Iron and Steel Industry*, 1914–18, p. 125.

[2] *Ibid.*

[3] C.R. 4368.

[4] See above, p. 2.

from home ores. A committee on home ore supply was formed, under Sir John Hunter as chairman, with Colonel Wright as deputy chairman, the work being distributed as follows :—

Mr. A. K. Reese .. / Mr. C. G. Atha ..	Basic pig iron and steel production.
Mr. B. Walmsley	Allocation of pig iron to steel furnaces.
Mr. F. Merricks .. / Dr. F. H. Hatch ..	Mining and quarrying of iron and manganese ores and limestone.
Mr. W. J. Jones	Supply of refractory materials.
Mr. P. G. Lewis	Supply of coal and coke.
Mr. T. M. McAlpine ..	Supply of mining machinery.
Maj. R. A. Laws (Secretary)	Supply of labour.
Mr. R. E. Palmer	Transport.
Mr. F. L. McLeod / Capt. R. J. Wallis-Jones	Foreign ore.
Mr. F. W. Harbord ..	Metallurgical Consultant.

A scheme was drawn up, under which the iron mines would produce, by the end of August, 1917, an increased output of iron ore at the rate of 4,000,000 tons per annum. This was to be obtained by a progressive weekly increase, which would by the end of the period have reached 80,000 tons a week above the weekly average for the first quarter of 1917. From this enlarged supply of ore it was hoped to produce an increased output of 1,000,000 tons of basic pig iron a year. Later investigations proved that the metallic content of the phosphoric ores of the country was higher than had been at first estimated, so that only 3,000,000 tons of home ore would be required for the production of 1,000,000 tons of pig iron.

In March, 1917, a branch was formed under Mr. Merricks and Dr. Hatch to deal with the mining and quarrying of iron ore, manganese ore and limestone. The country was divided up into five districts (Cumberland and Lancashire, Cleveland, Midlands, North Lincolnshire and Oxfordshire), each in charge of a Resident Mining Engineer, whose first duty was to obtain statistics of the production of ore. These five districts accounted for over 91 per cent. of the total production of ore in the United Kingdom.

(*a*) Hematite Ores.

The Cumberland and Lancashire district produced practically the only hematite iron ore in the country. West Coast ore was divided into three classes—blast ore, which was consumed in local blast furnaces ; lumpy ore, a specially pure hematite, which was used in the Midland blast furnaces for oxidising ; and annealing ore, which was also sent to the Midlands and used in the manufacture of malleable castings.

The West Coast ore had engaged the attention of the Ministry of Munitions from the outset, since its possible use as a substitute for

Swedish material made it of great importance. Sir L. Llewelyn reported in October, 1915, on the possibility of increasing the output of the large Hodbarrow mines, by alterations in working methods. It appeared that the manager and many of the miners had joined the Army and the release of as many as possible was obtained.[1] In the same month the Ministry opened negotiations with the royalty owner and the lessee of the Parkside mine, with a view to increasing the production of the mine.[2]

Labour difficulties were foreshadowed at the outset of these negotiations and throughout the war no substantial increase of output was obtained. Further negotiations took place in July, 1916, with the same object of increasing output and meetings were held at the Ministry between representatives of the mine owners, royalty owners and the miners. The latter took strong objection to any increase in royalties being obtained through a relaxation of their rules of working and concessions were agreed upon by both mine owners and royalty owners.[3] During the first half of 1917 continual demands were made for concessions both as to wages and with regard to the status of new labour imported into the district. Attempts to settle these difficulties failed and, after various local strikes, the Cumberland Iron Ore Miners Association resolved on 4 July, 1917, on a strike, which lasted till 27 August.[4] Under the scheme drawn up by the Home Ore Supply Committee, the output of the hematite mines was to be increased by about 400,000 tons per annum,[5] but the difficulties with the miners made a general increase in the district impossible.

As a result of the strike the Cumberland and Lancashire mines were taken over by the Ministry of Munitions as from 1 August, 1917. The terms were set out in an agreement dated 27 December, 1917, in which it was provided that the owners should receive as compensation for loss of profits and exhaustion of their mines, a fixed sum per ton raised, calculated on the pre-war profits of the mines. In cases where there were no pre-war profits which could be taken as a basis, it was provided that a fair and equitable rate should be agreed upon.[6]

In October, 1917, arrangements were made for the introduction of Scottish miners into the district; about 542 were eventually brought to camps, which had already been erected, their pay being fixed at a flat rate of 11s. 3d. per shift with war bonus and subsistence allowance, the latter being paid by the Ministry of National Service.[7] Their introduction was not a great success; many of them drifted back to Scotland and at the time of the Armistice only 100 remained.[8] In

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[1] C.R. 2661.
[2] HIST. REC./R./1810/45.
[3] HIST. REC./R./1810/40; Sir L. Llewelyn's Papers, 254A.
[4] *Iron and Steel Industry*, 1914–18, p. 24.
[5] HIST. REC./R./1810/16.
[6] C.F.A.C./Gen./30.
[7] M.C. 131.
[8] C.I.S.P./Dep./35A; *Iron and Steel Industry*, 1914–18, p. 85; M.C. 131; L.R.234/20.

1918 the calling up of miners to the Army again led to labour difficulties, but the strike which followed the " comb out " came to nothing.[1]

In spite of all the efforts of the Ministry of Munitions, the output from the West Coast mines never reached the 1913 figure of 1,767,088 tons. The yearly production during the war was as follows:—[2]

	Tons.
1914	1,630,682
1915	1,656,494
1916	1,608,353
1917	1,586,429
1918	1,549,962

(*b*) Phosphoric Ores.

The chief work of the Home Ore Supply Committee was to increase the output of phosphoric ores, which could be used for basic, foundry and forge pig iron. The Mining Section carried out an extensive investigation of all the iron fields in the United Kingdom, but except in the Jurassic deposits of the Midlands and the Cleveland district, no large source of increased supply was discovered. At the end of 1916, Mr. J. E. Stephenson investigated the Jurassic ironstones. In Cleveland little increase could be expected, but in Lincolnshire, Northamptonshire, Rutlandshire, Leicestershire and Oxfordshire, the supply was practically unlimited. The essential difficulty was the supply of labour, but as the ironstone for the most part lay near the surface, a large increase in output could be obtained by the introduction of steam navvies and other machinery. This machinery was supplied by the Ministry and allocated to the different companies by the Resident Engineers.[3]

Investigations undertaken by the Ministry early in 1917 showed that the output of ore could be largely increased by the better organisation of railway transport. With the existing labour, it was reckoned that the output could be increased by 25 per cent. if the necessary railway wagons were available.[4] This was especially the case in the Midland districts. In March, 1917, it was decided that 4,000 extra wagons were necessary for the ore traffic and orders were to be placed for them by the Ministry as soon as the design was fixed.[5] In the meantime the Coal Controller placed at the disposal of the Ministry 1,000 colliery wagons, which were allocated before 16 April, 1917,[6]

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[1] L.R. 234/20

[2] *Iron and Steel Industry*, 1914–18, p. 122.

[3] *Iron and Steel Industry*, 1914–18, p. 74. Home Ore Supply Committee Reports, 7 March, 1917, 6 April, 1917, 26 July, 1917. (Hist. Rec./R./1810/80.)

[4] *Ibid.* 7 March, 1917.

[5] *Ibid.* 26 March, 1917.

[6] *Ibid.* 16 April, 1917.

and promised a further 1,000, while another 500 wagons were commandeered from other sources.[1] At the end of the month the transport arrangements were working smoothly and each wagon was conveying more materials per week owing to the better organisation of the railways and mines.[2] A railway was also built, by the labour of German prisoners of war, to connect the large Oxfordshire iron field with the Great Western Railway at Banbury and facilitate the transport of ore to the South Wales furnaces. The mining companies were urged by the Ministry to minimise their transport requirements by calcining the ore wherever possible before it was despatched from the quarries or mines.

Additional labour was transferred from various sources. Men from the Cornish clay mines were transferred to Lincolnshire to work at the Frodingham quarries, while in the Midlands a considerable number both of civilian prisoners and prisoners of war were employed.[3] In the Kettering district camps for 200 prisoners of war were erected at Carby, Wakerley and Rothewell, and similar camps were erected at Uppingham and Glendon and elsewhere. Hutments were also provided to accommodate the British labour transferred to the iron fields from other parts of the country.[4]

An iron ore mine in the Island of Raasay, off the West Coast of Scotland, was also developed through the action of the Ministry of Munitions. The mine was taken over from the company which worked it under an agreement, as from 1 June, 1916. The Ministry paid all costs of production, the firm bearing half the capital expenditure and retaining the assets at the end of the agreement, which was terminable by the Minister of Munitions at three months' notice.[5] Labour was provided by 300 prisoners of war, for whom camp accommodation was provided by the Ministry.[6] In February, 1919, as the production of this mine was no longer needed by the British Government, the agreement with the company was terminated.

The Home Ore Supply Committee was extremely successful in increasing the supply of phosphoric ore. Labour difficulties were surmounted and the efforts of the committee were only limited by the fact that the blast furnaces could not increase their capacity sufficiently rapidly to absorb all the available ore. During 1917 the average weekly output of ore of all kinds during the four quarters of the year was 272,544 tons, 288,736 tons, 295,522 tons, and 303,950 tons; the actual increase obtained per week in the fourth quarter, over the first quarter, was 21,406 tons, or at the rate of 1,633,112 tons per annum.[7]

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[1] Home Ore Supply Committee Reports, 23 April, 1917.

[2] *Ibid.* 30 April, 1917. *See also* M.C. 520; M.W.B. 1164; *Iron and Steel Industry*, 1914–18, p.75.

[3] *Ibid.*, p. 51.

[4] Home Ore Supply Committee Reports, 7 March, 1917, 2 April, 1917, 30 April, 1917.

[5] Hist. Rec./R./1812/2.

[6] *Iron and Steel Industry*, 1914–18, p. 53.

[7] C.R. 4368.

(c) WELSH MANGANESE ORES.

In view of the decreasing imports of manganese ores from India, the Home Ore Supply Committee also took steps to increase the production of the Welsh manganese mines. In July, 1917, Mr. Merricks inspected the properties situated in the Rhiw district, near Pwllheli, in North Wales. In 1914, the output of manganese ore in Wales had fallen to less than one-half of the 1913 output, but the enterprise of the companies had resulted in a considerable recovery in the following years.

Mr. Merricks found that one company had a stock of 4,000 tons, of which 2,500 tons were at the wharf, but 1,500 lay two miles away awaiting the renewal of a tramway to bring it to the wharf. Efforts were made by the Steel and Iron Production Department to provide transport facilities for the ore, and Colonel Wright, on 19 July, 1917, obtained a promise from the Director of Coast Shipping to supply boats to remove the accumulations to ports, whence it could be distributed to the works. By reopening an old shaft, the company hoped to double their existing weekly output of 100 tons.

The second company had no stocks, as their output of ore, about 100 tons a week, was carried in motor lorries to Pwllheli railway station. The company could more than double its output from the existing shaft if more labour were available, and this the Steel Department undertook to find, together with timber for rebuilding a pier, connected with the mine by an aerial railway.[1] These efforts were attended by greater success than Mr. Merricks had estimated and the production of Welsh manganese ore rose from 5,140 tons in 1916 to 13,094 in 1917, and 14,942 in 1918.[2]

III.—Development of Pig Iron Production.

At the outbreak of the war the position as to pig iron supplies was favourable for the immediate supply of munitions material, as the ironmasters had large stocks of hematite pig iron on hand. A period of exceptional prosperity in the steel industry had just come to an end. Cheap continental steel was coming into Great Britain in considerable quantities during 1914 and British firms could not dispose of their pig iron. During the first years of the war these stocks were drawn on continually, but in the summer of 1916 they had practically come to an end and a crisis in the supply of pig iron had to be faced. The Steel Department had from the outset made efforts to conserve supplies; the price of hematite pig iron was fixed at £6 2*s*. 6*d*.[3] per ton, and the export of pig iron with low percentages of phosphorus and sulphur was prohibited at the close of 1915;[4] while extensions to blast furnaces were arranged.[5]

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[1] Home Ore Supply Committee Report, 23 July, 1917.
[2] *Iron and Steel Industry*, 1914–18, p. 78.
[3] *See* below, p. 114.
[4] Sir L. Llewelyn's Papers, 275.
[5] *Ibid.* 254.

In 1914 the output of pig iron had dropped by 1,336,542 tons from the total obtained in 1913, while exports had fallen from 1,124,181 tons in the former year to 780,763 tons, with the final result that the pig iron available for home consumption in 1914 was only 8,000,000 tons instead of 9,000,000. The drop in output occurred in all kinds of pig iron, as may be seen from the following figures :—

	Output of Pig Iron in Great Britain.[1]	
	1913. Tons.	1914. Tons.
Forge and foundry iron	3,801,547	3,369,516
Hematite	3,604,823	3,225,403
Basic	2,529,800	2,002,500
Spiegel-eisen, ferro-manganese, etc.	324,145	326,354
Total	10,260,315	8,923,773

As in the case of iron ore, the Steel Department was mainly concerned at first with the increase of hematite material. By February, 1916, returns were obtained from individual iron manufacturers of their stocks of hematite pig iron, their output and their commitments. These returns showed that the stocks at the end of January, 1916, amounted to 114,900 tons, the total output for the month of January was 216,000 tons, and the total commitments for home and export amounted to 247,314 tons for February. It was reckoned, therefore, that stocks would be exhausted in four months.[2] Certain firms had already been approached with a view to putting more furnaces into blast, but the difficulty lay in increasing the supply of foreign hematite iron ore.[3] By the middle of February, 1916, blast furnace extensions had been arranged at the works of eleven firms in Scotland, and the increased output was expected to mature about June or July, but the working of nine of these extensions depended upon the receipt of 8,200 tons of Spanish ore weekly. One of the extensions involved the change from foundry iron to hematite and in only one case was an increase of basic pig iron arranged for.[4]

In order to ensure the best allocation of ore, various local committees were appointed. In the North East Coast district three committees were set up in 1916. A local Control Committee was established in March, 1916, at Middlesbrough, composed of ironmasters, who dealt with all questions relating to pig iron both for home and export purposes. Another committee—of ironfounders—allocated Cleveland foundry iron in England. A third committee, known as the Limestone Control Committee, composed of representatives of ironmasters, quarry owners, and of the North Eastern Railway Company, organised the supplies of limestone to the blast furnaces in the district.

[1] *Iron and Steel Industry*, 1914-18.
[2] Sir L. Llewelyn's Papers, 254.
[3] See above, p. 26.
[4] Sir L. Llewelyn's Papers, 254.

In Scotland, both an Advisory Committee, which acted generally, and a committee of ironfounders, which dealt with the Cleveland foundry iron imported into Scotland, were established. The allocation of iron ore to the different blast furnaces was controlled by four local committees of ironmasters for the districts of the North East Coast, Wales, the North-West Coast and Scotland. Each local committee sent two representatives to a central committee in London, under the chairmanship of Mr. McLeod.[1]

In May, 1916, the output of pig iron was placed under the supervision of Mr. Walmsley, who came to the Ministry of Munitions for this purpose. He decided that the output of hematite pig iron must be allocated to the steel works month by month to obtain a fair distribution of the supplies. Hematite pig iron was in consequence controlled from July, 1916.[2] A conference was held at the Ministry on 17 May, 1916 to consider how to increase the pig iron output by 3,172,000 tons a year to meet the increasing demands for steel. Returns obtained by the Ministry showed that there were 501 blast furnaces in Great Britain, of which only 288 were then producing iron. Arrangements had already been made to put another 50 into blast, while the remaining 163 were mainly furnaces of obsolete type.[3] In the meantime certain steel extensions had to be postponed until the supplies of pig iron had been increased.

An increase in the supply of pig iron depended not only on the supply of various materials, but also on obtaining labour and transport facilities. The building of 16 new furnaces was sanctioned by the Ministry of Munitions, but their erection suffered continual delays owing to the difficulty of obtaining materials and machinery, while, owing to increasing cost of constructional work, the original estimates had to be frequently revised.[4] By September, 1916, arrangements had been made for the increased production of hematite pig iron at the rate of 25,600 tons a week, and of basic pig iron at the rate of 15,500 tons a week. Many firms, however, were working their stand-by furnaces, and as many furnaces would have to go out for repairs, a reduction of output would follow. The stocks of hematite iron were exhausted, while the production of basic pig iron showed a weekly shortage of 5,321 tons against the steel makers' requirements.[5]

The steel and iron position was, therefore, critical. The department having been reorganised,[6] Sir John Hunter put forward in October proposals for a further increase in the output of steel ingots of 3,000,000 tons per annum, to be accompanied by extensions of blast furnaces and coke ovens to give the necessary increase of pig iron and coke. It was estimated that provision would have to be made for an additional output of 14,864 tons of hematite pig iron

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[1] Sir L. Llewelyn's Papers, 254; C.R. 4368.
[2] *Iron and Steel Industry*, 1914–18, p. 20.
[3] HIST. REC./R./1810/41.
[4] *Iron and Steel Industry*, 1914–18, p. 45; Sir L. Llewelyn's Papers, 175; D.S.P./B./20, 28.
[5] C.R. 4508.
[6] A.C. 53.

and 15,071 tons of basic pig iron per week, and Sir John Hunter, on 17 October, 1916, approved a number of schemes for extensions to blast furnaces designed to produce 12,500 tons of hematite and 18,000 tons of basic iron. The extensions were to begin working at various dates ranging from January 1917 to April 1919.[1]

The work of increasing the pig iron output was taken over, at the beginning of 1917, by the Home Ore Supply Committee. As the supply of hematite ore imported into the country could not be maintained in face of the German submarine campaign,[2] the committee concentrated its efforts on the production of a basic pig iron suitable for conversion into steel. At first, however, it was hoped to increase the pig iron output in the north-west coast district, where there were 15 idle blast furnaces in April, 1917. Ten could have been put into operation in four to five months and would have produced from 7,000 to 8,000 tons of hematite pig iron a week, but, owing to the failure to increase the ore output of the local mines referred to above, it was impossible to realise this programme.[3]

The basic programme was dealt with by a section of the Iron and Steel Department, under Mr. A. K. Reese, General Manager of Messrs. Guest, Keen & Nettlefold's works at Cardiff, and Mr. C. G. Atha, General Manager of the Frodingham Iron & Steel Company, Lincolnshire.[4] Basic pig iron, which could replace the decreasing supplies of hematite pig iron, had been made successfully from North Lincolnshire ores, and also, with the addition of certain materials, from Midland ores. The section had, however, to face the fact that both the Cleveland and Midland ironstones, the chief source of raw material available, were not in themselves suitable for steel making, while the iron masters in these districts were mainly accustomed to the manufacture of forge and foundry iron. The first step was to fix the percentages of sulphur and silicon which would be accepted by the steel makers. A meeting was held for this purpose at the Ministry of Munitions on 2 March, 1917, when, after much discussion, it was agreed that pig iron produced in basic open-hearth furnaces might contain a maximum percentage of 1·5 of silicon and of ·1 of sulphur, and a minimum percentage of 1·25 of manganese.[5]

The Home Ore Supply Committee circularised all the iron masters asking for returns of furnaces suitable for working British ores. Replies were received from 20 firms who had 52 idle furnaces, and the Ministry asked for further information as to materials and labour necessary for putting these furnaces into blast and also offered to give expert advice on basic pig iron manufacture. By April, Mr. Reese and Mr. Atha had persuaded seven firms to make the experiment, and several more were confident that they could successfully manufacture pig iron of the required quality. Of the idle furnaces, 36 were

[1] A.C. 53.
[2] See above, p. 28.
[3] Home Ore Supply Committee Reports, 6 April, 1917 and 23 April, 1917.
[4] *Ibid.*, 7 March, 1917.
[5] *Iron and Steel Industry*, 1914–18, pp. 43 and 44.

in the Midlands, 12 on the North-East Coast, two in Scotland and two in Wales. By the end of the half year, 16 were ready to be put into blast, but other firms needed additional engine blowing power, etc., and another six months would elapse before their furnaces could be blown in.[1]

Besides the erection of new blast furnaces, and the putting into blast of idle or stand-by furnaces, an increase of basic pig iron was obtained by changing over existing furnaces from hematite pig iron or from forge and foundry iron. In September, 1917, it was found that the change over from acid to basic lined steel furnaces had progressed so far, that further provision of blast furnaces was necessary, and negotiations were undertaken with three firms for the erection of new furnaces, and with four other firms for the re-equipment of existing furnaces, so that a total additional output of 10,000 tons a week of basic pig iron might be obtained. In order to finance these schemes, the Steel Department proposed that an amount not exceeding 50 per cent. of the cost should be written off from excess profits or given as a direct grant. The scheme approved by the Minister on 2 October, 1917, provided for an estimated expenditure of about £1,350,000 to produce an increased weekly output of 10,700 tons of basic pig iron by the end of 1918, the contribution of the Ministry amounting to 45 per cent. Apart from these grants, loans might be made to some of the companies to cover the balance of the expenditure, on the condition that satisfactory security was given, and that the loans were made on the usual terms in regard to interest and repayment. The financial arrangements were finally approved by the Treasury on 4 December, 1917.[2]

The weekly output of basic pig iron, at the inception of the home ore programme, was 47,920 tons, and the maximum output after extensions had been made to basic blast furnaces was reached in the week ending 5 May, 1918, when 65,530 tons were obtained.[3] After that date the output was seriously affected by the calling up of a large number of men to the Colours. At the end of June, 1918, 13 blast furnaces, which would give a weekly output of 7,380 tons, were ready to be blown in, but they required 473 additional men before being put into operation.[4]

This was no new difficulty, as the production of pig iron had been hampered throughout the war by lack of suitable labour. Not only had skilled men joined the Army, but young and strong men were essential for the unskilled work, particularly for unloading ore at the blast furnaces and similar work. No scheme for dilution by women workers was possible. In the summer of 1917, it was found that additional furnaces, which had been completed, could

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[1] Home Ore Supply Committee Reports, 26 March, 1917, and 6 April, 1917.

[2] D.S.P./Gen./61. A subsidiary scheme for the erection of bye-product ovens and recovery plant to provide the extra coke required at an estimated cost of £1,350,000, was approved at the same time.

[3] *Iron and Steel Industry*, 1914–18, p. 48.

[4] C.I.S.P./Dep./35A.

not be put into operation owing to lack of men, and steps were taken to obtain the consent of the War Office for the return of blast furnace operatives from the Army. The names of these men were furnished by the different ironmasters to the Iron and Steel Department, who passed on the lists to the Labour Supply Department of the Ministry, on whose application the men were released. Many of them were serving abroad, so that they returned in small numbers and at considerable intervals, but gradually with their help and further supplies of labour obtained at home, a certain number of blast furnaces came into operation and the output of pig iron increased. Arrangements were also made to protect the men already working at the blast furnaces, when the Munitions Area Recruiting Scheme was introduced.

In September, 1917, it was arranged that Mr. Reese, who was in charge of the pig iron section of the Steel & Iron Department, should also deal with the supply of skilled labour for blast furnaces. This work continually grew and became more and more difficult, as the increased demands of men for the Army coincided with the completion of new blast furnaces. In February, 1918, the Minister agreed to release a large number of men from munition work for the Army, and at many iron and steel works the numbers were reduced to the absolute minimum required. As a result, the labour for the extensions completed in June, 1918, was not forthcoming, and matters were complicated by difficulties arising with the War Office over the release of skilled men from the Colours. Finally, at the end of the month came the " clean-cut " by which the blast furnaces lost 600 men. At some works, furnaces were blown out, while at others furnaces were put on slack blast. The pig iron programme could no longer be carried out and the output dropped. Some relief was obtained by the return of some 120 men, who had previously been released, but the situation became so serious that on 22 July, 1918, the Iron and Steel Department asked for the return of the men called up under the clean-cut.[1] Arrangements were made for the release of 475 men, for which the sanction of the War Cabinet was obtained on 22 September, 1918, and it was expected that the output of pig iron would be raised by 5,000 tons per week.[2]

IV.—Extensions to Coke Ovens.

Metallurgical coke is chiefly used in blast furnaces in the manufacture of pig iron, and by-products from coke by-product ovens were needed in the supply of high explosives. Of the three types of oven used for the production of coke—by-product, non-recovery retort and beehive—by-product ovens are the most modern and the most economical, but though for many years they have been practically universal on the Continent, their adoption was delayed

[1] C.I.S.P/Gen./22.
[2] *Iron and Steel Industry*, 1914–18, pp. 48–50, 55.

and impeded in Great Britain owing to the prejudice of iron-smelters against by-product coke as a blast furnace fuel. This prejudice was only slowly overcome. During the ten years immediately preceding the war there was a rapid development in by-product coking in Great Britain, about eight times the quantity of coke produced in by-product ovens in the year 1903, being produced in the year 1913.[1] In 1914, rather more than half of the coke output (which amounted to 11,059,000 tons), was produced in by-product ovens from which were obtained benzol and toluol, required for the manufacture of picric acid and T.N.T., and also for the manufacture of dyes, sulphate of ammonia, used as a nitrogenous fertiliser and in the manufacture of ammonium nitrate and ammonium perchlorate, and creosote, required as a fuel oil by the Admiralty. These by-products were controlled by the Explosives Supply Department.[2]

Fluctuations in the price of metallurgical coke bewildering to the producer, followed the outbreak of the war and complicated production and distribution. During 1914, the production of pig iron decreased, thus reducing the demand for coke, while the introduction of by-product ovens was increasing the coke output. This resulted in a glut of coke which brought about a great fall in price. At the outbreak of the war, coke was in many cases being sold at a figure equal to the cost of the coal put into the ovens, *i.e.*, at a heavy loss to the makers. In the early part of 1915, however, there was a rapid advance in price, this being due to a considerable number of old-fashioned ovens of the beehive type having been put out of commission, and to the extra demand for coke due to the increased manufacture of pig iron for munition purposes. But later in the year the growing demand for the coke-oven by-products (toluol and benzol), and the production of these materials by the owners of coke by-product ovens, resulted in a surplus of coke, and in October, 1915, a committee was appointed by the Minister of Munitions to consider and report as to the best means of dealing with the supplies of metallurgical coke produced in the United Kingdom, in order to maintain and as far as possible to increase the supply of the by-products necessary for the manufacture of high explosives.[3]

Before the report of the committee was published, however, the position had again changed owing to the removal by the Board of Trade of restrictions in respect to the export of coke and in December, 1915, the coke shortage was such that several blast furnaces had been put on slack blast. This shortage was accentuated by the necessity of meeting large war demands, amounting in the aggregate to over a million tons per annum, from France and Italy, who formerly drew their supplies from Belgium and Germany. Accordingly the Coal and Coke Section of the Ministry of Munitions was formed under Mr. P. G. Lewis, at the end of December, 1915,

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[1] X235/46, 163.
[2] See Vol. VII, Part IV, Chap. II.
[3] X235/163.

and it was decided that it would be necessary to control prices. In January, 1916, therefore, maximum prices were fixed for metallurgical coke in Scotland, Durham, South Wales and the Midlands (including Lancashire and Yorkshire).[1] The system of control then set up continued throughout the war, subject to certain adjustments made from time to time. At the same time, by arrangement with the War Trade Department and the Coal Exports Committee, a system of licenses for the export of coke was re-introduced. Urgent appeals were also issued to all coke makers to increase their production as rapidly as possible, and by the end of March, 1916, current requirements were being met.

The large programme for the increased production of pig iron and steel adopted in April, 1916, meant increased demands for coke, and during the next six months detailed plans were formulated to meet these. The first printed programme, dated 27 June, 1916, called for an extra 39,546 tons of furnace coke per week, of which over 21,000 tons per week were to be furnished in four months. Under the second programme, dated 30 September, 1916, the requirement had been increased to 53,462 tons per week, representing the needs of 57 additional blast furnaces which were to be brought into operation as quickly as possible, chiefly to produce basic pig iron from home ores.

Of necessity, these demands fell chiefly on collieries situated in the Midlands, where the output of coking coal was already short and was being still further reduced by the recruitment of coal miners for the Army; for, owing to the necessity of furnishing coke to the blast furnaces at a reasonable price, it was not possible to import coke to the Midlands from South Wales or Durham where adequate supplies of coking coal existed.

During the whole of the year 1916, production was organised on a rapidly increasing scale to meet the current demand, while it was hoped that the installation of new plant would enable pig iron and steel to be produced at a price which would stimulate the export trade at the end of the war. Throughout there was close co-operation between the Coal and Coke Department and the Explosives Supply Department.[2] In the late autumn of 1916, various agreements negotiated by the Explosives Supply Department for extensions to coke ovens producing coke, toluol and benzol were entered into. These extensions were to be completed in six months. In each case an allowance was to be written off out of excess profits, this allowance varying from 25 per cent. to 37½ per cent. of the approved cost of the extensions.[3] Efforts were made to increase the output per oven by the use of higher temperatures, and in some cases by the reduction of the moisture in the washed coal charged into by-product ovens. As a result the average output per oven was in the year 1916 raised to 1,320 tons per annum as compared with 1,133 tons per annum in 1915, an increased efficiency of 17 per cent.

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[1] See below, Chap. VI. [2] 94/Misc./190. [3] X. 235/34.

By May, 1917, extensions for increasing the production of metallurgical coke by 793,998 tons per annum, involving a total capital expenditure of £1,271,152, had been approved.[1] This production was to be secured by the erection of new by-product coke ovens in connection with collieries in different parts of the country. Contributions towards the approved cost were to be made by the Ministry, the general principle adopted at this time in connection with schemes for extending the production of steel being that a proportion of the capital cost of the extensions was to be met by a writing off from the excess profits of the firms concerned, within the limits authorised by the Munitions of War Act, 1915, or from allowances granted for increased output.

As the demand for coke was urgent, pending the completion of the bye-product ovens, certain guarantees were given in regard to the repair and working of beehive ovens which had become obsolete owing to the competition of bye-product ovens. The original proposal submitted to the Finance Department on 8 December, 1916, asked for authority to repair up to 4,000 beehive ovens at an average cost of £30 per oven.[2] Later the difficulty of obtaining adequate supplies of hematite iron ore made it necessary to divert to basic pig iron manufacture blast furnaces which had been listed for hematite pig iron, the consequent delay reducing the urgency of the demand for coke, while the reduction in the tonnage available for exporting coke also made the home market easier. In July, 1917, it was decided that the reduced demand for coke could be met by the repair of some 2,000 selected beehive ovens at an average cost of about £12 per oven, instead of the number originally proposed, and it was reported that certain of these ovens had already come into operation.

The estimated output of coke from these beehive ovens was over 600,000 tons per annum, the ovens being distributed as follows:—

District.	Number of ovens to be be repaired	Estimated cost of repair.	Government contribution.	Number restarted to 30 April, 1917.
		£	£	
Durham	1,594	20,431	20,431	284
S. Yorkshire	142	1,310	655	49
W. Yorkshire	56	500	250	7
Derby, Lincoln & Notts	10	70	35	—
Lancashire & Cheshire	67	423	212	—
Special cases .. {	12	130	65	—
	120	1,920	960	—
	2,001	£24,784	£22,608	340

[1] 94/S./2846.
[2] 94/S/2846; D.D.G.M., 924.

By 30 April, 1917, 340 of these ovens were being worked,[1] and in all over 800 beehive ovens, which had been abandoned, were repaired and put into operation.

On 11 August, the Ministry informed the Treasury that it was not proposed to re-start immediately all the ovens which had been or were being repaired, but it was regarded as essential that they should be available for use if required. It was not possible at the moment to furnish an estimate as to the probable financial effect of the guarantee given by the Minister to meet such losses as might be incurred by the competition of the by-product ovens, from the more economical production of which requirements would as far as possible be met.

On 1 March, 1917, a Controller of Coal Mines, Board of Trade, was appointed, and the control of supplies of coal to munition works of all kinds was transferred to him. The Coal and Coke Department of the Ministry of Munitions continued, however, to deal with all questions relating to the production and distribution of metallurgical coke.[2] As a result of conferences on 6 and 12 July, 1917, the Coal Controller agreed not to bring coke ovens under his control as regards finance.[3] A proposal had been made to bring coke ovens into the Coal Controller's scheme in order that 95 per cent. of the excess profits should be secured as in the case of collieries, but this proposal was vigorously opposed by the Ministry of Munitions. The Explosives Supply Department urged that if coke ovens were taxed to the extent of 95 per cent. of excess profits it would discourage the industry at a time when largely increased production of benzol, toluol, naphtha and fuel oil was required, while Mr. P. G. Lewis, representing the Iron and Steel Production Department, pointed out that in conjunction with the Explosives Supply Department, he had been able to speed up the plants from 78 per cent. to 96 per cent. of potential capacity, but that it was not possible to maintain an increased standard of efficiency for any length of time unless the work was remunerative to the producers.[4]

Later, in 1918, Mr. P. G. Lewis was appointed Liaison Officer between the Ministry of Munitions and the Coal Controller's Department, and also chairman of a committee dealing with coal and coke supplies within the Ministry. This was at a time when serious difficulties were anticipated in obtaining adequate coal supplies for munitions works in consequence of the recruitment of coal miners and the necessity of increasing supplies to France.[5]

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[1] 94/S./2846.

[2] X.235/143.

[3] 94/Misc./190.

[4] 94/Misc./190.

[5] C.I.S.P./Dep./35A.

During 1917, the production of metallurgical coke was 13,862,000 tons. This was produced in the following districts in the proportions given :—

Districts Producing Metallurgical Coke.

District.	*Percentage Rates to total Production.*
Durham	39
Yorkshire	26
South Wales	12
Shropshire, Staffordshire and Worcestershire	5
Derbyshire, Lincolnshire and Nottingham	5
Lancashire and Cheshire	5
Cumberland	4
Scotland	4
	100

The consumption of coke in blast furnaces in the United Kingdom during 1917, was 11,140,000 tons, i.e., 80 per cent. of the total production of metallurgical coke. This was consumed in the following districts in the proportions given :—

Districts consuming Furnace Coke.

District.	*Percentage Rates to total Consumption.*
Cleveland, Durham and Northumberland	36
Midlands, including South Yorkshire ..	24
Cumberland	14
Shropshire, Staffordshire and Warwickshire	9
South Wales	8
Lancashire, Cheshire and North Wales ..	5
Scotland	4
	100

By the middle of 1917, the rate of production exceeded the pre-war record by 1,100,000 tons per annum. Blast furnace requirements at this time amounted to 79 per cent. of the output, 6 per cent. was exported to France and Italy, and the remaining 15 per cent. was used for miscellaneous purposes such as engineering foundries and the manufacture of high speed tool steel in the Sheffield district.

During the latter part of the year 1917 and the year 1918 there were further considerable extensions to coke ovens, the greater part of the extensions made during the war being constructed during this period.

In May, 1917, the estimated capital expenditure for coke-oven extensions which had been approved was £1,271,152,[1] while the total cost of by-product coke ovens laid down during the war period was nearly £5,000,000. Towards this total cost the Ministry contributed £1,250,000. The number of by-product ovens laid down was over 1,750, and it was anticipated that when they were in full operation the output of coke from these ovens would be about 16,500,000 tons per annum, approximately a 50 per cent. increase upon the pre-war output. This increase in the production of coke would require 8,250,000 tons of additional coal per annum, representing the labour of 33,000 coal miners. The total quantity of coal that would then have to be carbonised for the manufacture of metallurgical coke would be 30,000,000 tons per annum, or 11 per cent. of the total pre-war output of coal in the United Kingdom.

The substitution of by-product coke ovens for beehive ovens was rapid. In 1913, 58 per cent. only of the coke output was made in by-product ovens, with the result that not only were valuable by-products lost, but labour and coal were wasted. By 1918, however, 80 per cent. of the production of metallurgical coke was obtained from by-product ovens, and of the remainder 16 per cent. was obtained from beehive ovens and 4 per cent. from non-recovery Coppée retort ovens.

It should be noted that selected beehive oven coke was considered essential for the carrying on of certain steel processes, especially in connection with the Sheffield trade, so that by-product ovens could not always be worked in preference to beehive ovens.[2] How rapidly the number of beehive ovens in the United Kingdom declined is shown by the following figures[3]:—

Year.	Number of Beehive Ovens.
1910	16,037
1911	14,301
1912	13,833
1913	13,167
1914	9,210
1915	7,521
1916	6,892
1917 (August)	7,143
1918 (October)	6,399

[1] 94/S./2846.
[2] X.235/163.
[3] X. 235/46.

In addition to a saving of over 800,000 tons of coal per annum, the following output of by-products was obtained :—

Material.	Controlled Price at the close of 1918.	Output per Annum
Sulphate of Ammonia	About £18 per ton.	165,000 tons.
Crude Benzol	,, 11d. per gallon.	34,000,000 galls.
Crude Tar	,, 30s. per ton.	450,000 tons.

The total value of the crude by-products obtained at the above controlled prices, exceeded £4,500,000 per annum, the value of the coke output being about £24,000,000 per annum. The number of ovens in operation on 31 October, 1918, was :—by-product—8,375 ; retort—1,334 ; and beehive—6,399.

The output, export and home consumption of metallurgical coke for the years 1914–1918, was as follows :—

Year.	*Output. Tons.*	*Export. Tons.*	*Home Consumption Tons.*
1914	11,050,256	—[1]	—[1]
1915	12,136,845	621,533	11,515,312
1916	13,422,195	1,130,203	12,291,992
1917	13,801,607	878,711	12,922,896
1918	13,301,548	634,773	12,666,775

The above figures show that the output for 1917 was 2,800,000 tons (equivalent to about 25 per cent.) greater than that for the year 1914. More than 4,000,000 tons of coal per annum was required in order to furnish this increased production, and this amount was forthcoming in spite of the loss in output resulting from the recruitment of miners. The coal required for the manufacture of metallurgical coke averaged 22,000,000 tons per annum.

Of the metallurgical coke exported during the year 1916, 65 per cent. was sent to France and 15 per cent. to Italy, the remaining 20 per cent. being sent to neutral countries in exchange for copper, lead and other important munitions materials. France had to draw largely on this country in 1916, owing to the loss of the coke ovens in the Pas de Calais coalfield. From the beginning of 1917 onwards, however, the French demands were reduced owing to her increased production,

[1] Figures for 1914 not available.

The policy of increasing the production of home iron ore, which was developed when shipping difficulties threatened to limit supplies of imported hematite iron ore, necessitated a larger coke consumption, for since the home iron ores were of low iron content (averaging 28 per cent. iron as against 50 per cent. for imported hematite), an increased number of blast furnaces were required to produce the same output of pig iron.

Some of the extensions to coke ovens planned in connection with schemes for increasing iron and steel production, were not completed till after the Armistice, but these schemes, providing, as they did, for the use of home ores for the basic process of steel making, and for the erection on the same site of self-contained works comprising modern coke ovens (equipped with by-product recovery plants), blast furnaces, steel works and rolling mills, were felt to be of permanent national importance. It was considered that by erecting coke oven plants in close proximity to blast furnace plants in steel works rather than at the collieries, economy in fuel would be effected, as blast furnace gas could be used for heating the coke ovens, thus setting free the whole of the rich coke oven gas for use in the steel furnaces and other heating processes.[1]

Increased coke output necessitated an increased output of the coke oven bricks required to repair the ovens and, at times, shortage of these bricks tended to limit coke production.[2] The necessary increase in their output was arranged for by the Iron and Steel Production Department.[3]

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[1] X.235/46. Report of Coal Conservation Committee, Appendix II.
[2] (Printed) *Weekly Report*, No. 106, III (25.8.17).
[3] See below, p. 87.

CHAPTER III.

THE DEVELOPMENT OF STEEL PRODUCTION.

I.—Early Extensions to Steel Works.

In the first months of the war, a certain number of steel firms enlarged their steel works, mainly on their own initiative and entirely at their own expense, in order to meet increased requirements for munition purposes. Thus, one well-known firm spent a considerable amount of money in increasing their machinery for the output of shell steel, and in October, 1915, were contemplating spending another £150,000.[1] Another firm had committed themselves in the same period to a capital expenditure of £229,300 in provision of coke ovens, new steel works, a new bar mill and a pickling and grinding plant for shell steel bars. After the formation of the Ministry of Munitions, the increasing pressure brought on the steel makers to enlarge their shell steel output forced them to reconsider their position, especially when this was viewed in connection with the new Budget proposals for the excess profits tax. It appeared that the extensions for shell steel would either be entirely unremunerative after the war, or would involve considerable expense in conversion for the production of ordinary steel; consequently directors of companies felt that they were not justified in incurring further capital expenditure for war purposes.[2] At the outset of the negotiations for increased output between the Ministry and the steel makers, the latter had been very anxious to avoid control by the Ministry, and for a time many of them were omitted from the lists of controlled establishments, on the understanding that the requirements of the Director of Raw Materials were fully met. A considerable number of large steel-making firms who also made munitions had been controlled previously, and when the question of government assistance in building extensions arose, control became a necessity, whether the assistance took the form of supplying labour or rendering financial help. The steel firms were, therefore, declared controlled on and from 8 November, 1915.[3]

To meet the 1916 programme, an increase in output of 2,300,000 tons of steel ingots was required, and during September, 1915, negotiations for steel extensions were carried on, some schemes being recommended for adoption in November. Two agreements were signed in that month for extensions giving an additional output of

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[1] Sir L. Llewelyn's Papers, 164.

[2] *Ibid* 20.

[3] Sir L. Llewelyn's Papers, 135.

7,500 tons a month, but, owing to delays in the Controlled Establishment Department, few schemes were sanctioned before February, 1916.[1] It soon appeared, however, that these extensions would be quite inadequate. At a conference on the steel situation (15 March, 1916), it was reported that the weekly requirements of shell steel for 1916 were as follows :—

(a) Finished steel for Ministry of Munitions	30,000 tons
(b) Admiralty shell steel	2,000 ,,
(c) French Government	20,000 ,,
	52,000 ,,

while the actual weekly deliveries amounted to 30,000 tons, showing a deficit of about 1,000,000 tons a year.[2]

II.—The Treasury Guarantee.

All the leading steel makers were urged to extend their works, but in nearly every case they pointed out that the present capital cost of extensions was very high, and that the market for steel after the war was uncertain. They declined, therefore, to proceed without government assistance, and asked that some arrangement might be made with the Controlled Establishments Department of the Ministry, whereby they might retain a definite proportion of the profits as a reward for increasing their production.

Schemes were submitted by 36 firms, five of whom afterwards withdrew their proposals.[3] It was arranged that Mr. Owen Hugh Smith should negotiate an arrangement for writing down out of their excess profits a fixed depreciation upon the cost of the extensions, in order to induce them to undertake the work.

Six firms, however, refused to accept this proposal, as they doubted whether their excess profits would be sufficient to meet the proposed charge for depreciation, and as they absolutely declined to proceed with their extensions on the proposed terms, the Finance Department was obliged to give them a guarantee that if their excess profits were insufficient to meet the required depreciation, the Ministry would make good the deficiency.

This guarantee, of course, required the sanction of the Treasury, for which the Ministry applied on 15 March. The six cases in which the guarantee had been given involved an ingot tonnage estimated at 477,500 tons a year and a capital cost estimated at £783,000. A proportion of this capital expenditure (say 25 per cent., or about £200,000), would, in any case, be provided by the steel makers out

[1] Sir L. Llewelyn's Papers, 20A.
[2] 94/S./2846.
[3] Sir L. Llewelyn's Papers, 20A.

of their own funds ; a further portion would be met by the steel makers retaining excess profits, and any sum remaining would ultimately form a charge upon the Ministry. The Ministry asked for authority to deal in a similar manner with any other cases that might arise.

On the following day three other steel makers, represented by Mr. Scoby Smith, announced that they declined to proceed with their extensions unless they had a similar guarantee, the capital expenditure proposed in these cases amounting to £1,000,000 sterling. Mr. Lloyd George concurred in the action that had been taken, as it was essential to give the guarantee in order to get the production.

The Treasury was of a different opinion :—

> " Mr. Lloyd George will no doubt recognise that it is a very extreme measure which could only be justified by a grave emergency to encourage steel production in this country on terms which amount to a free gift of a substantial proportion (which may be as high as 75 per cent.), of the capital expended. Even the allowance out of Excess Profits diverts a sum which, subject to the rules under the Munitions Acts, would otherwise have passed into the Exchequer."[1]

In the same letter, the Treasury drew attention to other difficulties. They assumed, on the basis, apparently, of information verbally communicated by Mr. Mann or Mr. Lever, that the capital cost of the extensions required to produce the necessary amount of steel would be between £3,000,000 and £4,000,000, and enquired whether the Minister was satisfied that he could obtain enough labour to work these extensions without withdrawing it from services just as essential, and whether the extensions could be completed in less than six months :—

The letter concluded thus :—

> " My Lords desire to commend these considerations to the attention of the Minister, observing that too ambitious an effort to increase steel production in this country would be apt to defeat its own ends, and result only in waste of effort and enhancement of wages and prices, and that it would be better to confine the proposals to a more moderate scale more capable of successful realisation."

The Ministry maintained its position (19 March 1916), and urged "with a full sense of responsibility, that in a matter so vital to the interests of the country and the conduct of the war, the necessary sanction should not be withheld." The only other way in which a sufficient supply of steel could be obtained by the autumn was by making additional purchases in the United States on a very large scale, and at excessive prices amounting to over £2,000,000 per month exclusive of freight, which would obviously involve serious problems of tonnage and exchange. The Treasury gave way on the principle of making

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[1] 16 March, 1916. (7112/16 in 94/S./2846.)

a capital advance to assist extensions, but refused to sanction any attempt to negotiate with the firms on the basis of allowing excess profits under the Munitions Act to be written off the capital charges incurred in the extension of plant.[1]

> "It is a cardinal principal of the national financial system that revenue cannot be intercepted for administrative purposes (except within closely defined limits), and it would be contrary to those principles to make the proposed arrangement, which is bound to affect sums which would pass to the Exchequer under the Finance Acts."

The Minister was authorised to negotiate with the firms upon such terms as he was able to secure on the basis that the firms must receive "as an advance, with or without interest, or as a free gift, such part of any excess over 25 per cent. of the capital cost of the extensions as they cannot be induced by the Minister of Munitions to bear upon their own resources."

The Treasury asked to be furnished with a summary of the arrangements made, and drew attention to the fact that a stringent control of the use of steel by other purchasers than the Government must be exercised if the scheme was to be justified, an attempt being made if possible to recover from such purchasers a part of the cost of the scheme to the Government.

On 22 March, Mr. Lever asked that the Ministry might be authorised to make agreements with the firms in the calculation of which reference was made to the sums payable as Income Tax and excess profits. The clause proposed was on the following lines:—

> "The Ministry will make a grant to the manufacturer free of interest at the end of the period of control equivalent to the sum by which his excess profits under the Munitions Acts, after the deduction of Income Tax and Excess Profits Duty, fall short of the depreciation, being the difference between the present cost and
>
> (*a*) estimated pre-war cost,
> or
> (*b*) 40 per cent. of the present cost,
> or
> (*c*) post control valuation."

The Treasury, while accepting this as satisfactory, urged that the Minister should try to secure that the cost of the extensions of plant should be provided for as a duly secured loan from the Ministry to the firm.[2] (25 March, 1916.)

A personal letter from the Chancellor of the Exchequer to Mr. Lloyd George (14 April) summarised the conditions agreed upon. The Minister was to make such financial arrangements with the steel makers as he found necessary, subject to the steel makers bearing

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[1] 20 March, 1916 (94/S./2846).
[2] 94/S./2486.

not less than 25 per cent. of the cost of the new plant as a final charge, and if these arrangements involved any reference to the amount the firms had to pay to the Inland Revenue as excess profits, the Minister would not remit the amount payable, but would repay an equivalent amount from the funds of the Ministry.

Construction began before the financial problem had been settled. By the middle of March, extensions were in progress, which would give an estimated output of 930,000 tons a year: negotiations for further extensions to give 984,600 tons a year were nearly completed. Four other companies had put forward schemes, involving an output of another 500,000 tons, but the negotiations were not far advanced.[1] It was hoped that these extensions would make the country independent of imported steel in 1917, but it quickly became evident that the Raw Materials Department had under-estimated the difficulties in attaining increased output.[2] In May, 1916, the extensions were not only held up owing to shortage of labour, but it was found that the schemes for steel extensions had outrun the production of pig iron and until the output of the blast furnaces, etc., had been co-ordinated, it was decided to postpone some of the proposed steel extensions.[3] There was therefore little prospect of increased output of steel until the second quarter of 1917.[4]

III.—Sir John Hunter's Scheme, October, 1916.

On the formation of the Iron and Steel Department, under Sir John Hunter, the whole situation was reviewed and extensions were planned on a scientific basis. Particulars were obtained of the existing plant at works where extensions were proposed, and the possibilities of increased output were considered from all points of view—transport, labour, supplies of raw materials and the existing lay-out of the works. Each district was also, so far as possible, made self-contained as to supplies of raw materials.[5] In June, 1916, plans were for the first time brought forward for the erection of a great national steel works, designed for an output of 12,000 tons a week. This plan had to be put aside in favour of extensions to existing works, as the construction would take probably from four to five years, and it was therefore a post-war scheme for which the country could not spare either the capital or expert talent.[6] The extensions sanctioned at this time were estimated to give an increased output of 2,500,000 tons by the end of 1917, while the actual output had been increased by 1,600,000 tons per annum.[7]

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[1] Sir L. Llewelyn's Papers, 20A.
[2] C.R. 4506.
[3] C.R. 4506. Sir L. Llewelyn's Papers, 175.
[4] C.R. 4506.
[5] *Iron and Steel Industry*, 1914–18, p. 39.
[6] C.R. 4506.
[7] C.R. 4506.

By September, extensions had been arranged for increased production of acid and basic steel ingots in Scotland, South Wales, Lancashire and Yorkshire, and the North East Coast. In addition, extensions in Cumberland for the production of acid steel, and extensions in Stafford, Derby, Lincoln and North Wales for the production of basic ingots were sanctioned. These schemes varied in detail, but all involved a government grant.

By these schemes it was planned to obtain a weekly increase of 19,455 tons of acid ingots and 36,680 tons of basic ingots in 1917, but in most cases the production of the latter would not begin till the Spring or early Summer of 1917.[1]

Besides extensions for increasing ingot capacity, another group of extensions were organised by Engineer Captain Richards, R.N., who was in charge of the Steel and Iron Tubes Section. By May, 1916, to meet the shortage in tubes, largely due to the demands of the Trench Warfare Supply Department and the Air Services, extensions were in progress or projected at Birmingham, Chesterfield, Dumbarton, Oldbury, Clydeside, Ebbw Vale, Walsall, Landore, Newport and Sheffield.[2]

Sir John Hunter realised that these extensions were not sufficient, as the total output of steel would only be brought up to 12,000,000 tons per annum by March, 1918, including certain extensions not yet authorised, while the requirements for different purposes already reached this figure and were steadily increasing. The submarine campaign had, in particular, made an increased supply of steel for shipbuilding of vital importance.[3] On 18 October, 1916, he approved nine additional schemes for steel works extensions, giving an increased weekly output of 4,500 tons of acid ingots and 7,900 tons of basic ingots. A tenth basic scheme did not involve an increased output of ingots, but by alterations in the plant a saving of 1,200 tons a week of hematite pig iron would be effected.[4] These extensions would complete the programme for a 2,500,000 ton increase, but there was still an estimated shortage of 3,000,000 tons of ingots, and, in October, an ambitious programme was put forward by the Steel Production Department to raise the annual steel production of the country to 15,000,000 tons and to secure the coke and pig iron supplies necessary to balance the increased steel capacity.

The proposals were divided into two groups. The first included five schemes for extensions and completion of existing works; the second included six schemes for entirely new self-contained works, to be erected at an estimated cost of £30,000,000. Nine of the schemes could use home ore, if imported ore was not obtainable; the tenth was for rolling mills only, and the eleventh consisted of the conversion of Bessemer furnaces to open hearth furnaces, thereby effecting a large

[1] C.R., 4508.
[2] HIST. REC./R./1810/2; Sir L. Llewelyn's Papers, 175.
[3] D.S.P./Gen./20.
[4] *Ibid.*

saving in pig-iron by the use of scrap. Sir John Hunter urged that the existing arrangements only carried the Department a little beyond the end of 1917; it was impossible to foretell the length of the war, and financially it was important to do everything possible to make Great Britain independent of supplies from America, which would mean a saving of £7 per ingot ton, or £21,000,000 per annum. It was, therefore, urgently necessary to increase the capacity of the British steel works at once. A long-sighted policy should be adopted, not only for war requirements, but to place the country in a strong position to meet the reconstruction programmes which would follow the restoration of peace. He proposed to approach six large firms, urging them to undertake the erection of complete new units, containing coke ovens, blast furnaces, steel works and rolling mills,[1] while, in addition, five extension schemes were proposed.[2]

In preparing these schemes special consideration was given to geographical distribution, the capacity of the management, the proximity of raw material and facilities for transport.[3] A conference was held on 23 October, 1916, at which Dr. Addison was present, together with Sir John Hunter, Mr MacLellan, Mr. John Mann of the Finance Department, and Mr. Maslin of the Contracts Department. After discussion of the financial side, Dr. Addison agreed that the schemes should be proceeded with, provided the following principles were adhered to. (1) The extensions should be thoroughly up to date, and the plant the best of its kind. (2) Preference should be given to contractors who proposed to effect such extensions as would make the plant complete in itself as regards the supply of raw material, manufacture, shipping, etc., unless it could be shown that where the plant was not properly balanced, the balancing units already existed elsewhere. (3) Post-war values and not pre-war values should be taken as the basis when conducting financial negotiations. (4) As far as possible, the schemes should be arranged on the basis that the writing off should be based on post-war value, with a minimum of 33⅓ per cent. and a maximum of 50 per cent. If it proved impracticable to get the contractors to agree to these terms, then Dr Addison indicated that an alternative might be found in the erection of national steel works, but this was not to be used in any way as a threat.[4]

In the closing months of the year the proposals of the Iron & Steel Department came in for some very searching criticism, especially from Sir L. Worthington Evans, the Parliamentary Secretary to the Ministry, in view of the fact that they could not be completed for 2½ years at the earliest, and that they would use labour and material urgently needed for war purposes. At his suggestion a committee was appointed, consisting of Sir A. Duckham, Sir John Hunter, Colonel Wright, Mr. F. W. Harbord and Mr. Hutchins (secretary), to consider the schemes for the six new units. They reported, on 17 January, 1917, that it was not advisable to put in hand the new works, mainly

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[1] D.S.P./Gen./20.
[2] C.R. 4368.
[3] D.S.P./Gen./20.
[4] C.I.S.P./Gen./67.

because their construction would interfere materially with the completion of extensions already authorised or suggested. The committee, however, urged that the plans for these new works should be further developed, so that when labour and materials became available the question could be reconsidered, and the new works started rapidly if necessary.

Extension schemes which had already been undertaken were on a different footing. In certain cases more rolling capacity was needed if the works were to be turned over, after the war, to commercial peace output in the shortest possible time. Sir L. Worthington Evans favoured carrying out the complete programme of extension schemes, as these would mature towards the end of 1917 and throughout 1918.[1] Schemes for the completion of these works were sanctioned by Dr. Addison on 20 January, 1917.[2] On 21 May, 1917, the Ministry reported to the Treasury on the progress of these extensions. The estimate of £3,000,000 to £4,000,000 put forward in March, 1916, had been increased to meet the larger schemes adopted in the autumn, and steel works extensions on 11 April, 1917, amounted to £14,672,695. In addition, nearly £5,000,000 had been advanced for increased production of pig-iron and of metallurgical coke.

The following summary of the extensions approved with a view to increasing the home output of steel was put forward:—

Class of Material.	*Capital Expenditure.* £	*Increase to be obtained.* Tons p.a.
Steel	14,672,695	4,411,500
Pig Iron	2,380,394	2,407,500
Metallurgical Coke.. ..	1,271,152[3]	793,988
Silica Bricks (number) ..	140,386	55,560,000
Miscellaneous Extensions and Sundry Materials ..	569,911	
	£19,034,538	

The nature of the agreements under which the extensions had been undertaken varied considerably. In most cases the firms had been unwilling to proceed without a definite agreement as to the percentage of actual cost which was to be regarded as post-control value, and it had been necessary to fix this percentage, allowing the contractors to write off the difference between actual capital expenditure and this post-control value.

In a few cases a guarantee had been given that in the event of excess profits not being sufficient to meet the writing off of capital expenditure allowed, a contribution would be made by the Ministry equal to the deficiency. In many cases the extensions had been financed from profits accruing from the work carried on in the firm's controlled establishments.

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[1] D.S.P./Gen./20.

[2] C.I.S.P./Gen./67 ; D.S.P./Gen./20.

[3] In a note dated 12 July, 1917, Sir John Hunter stated that he was unable to reconcile the capital expenditure and the additional quantity of metallurgical coke here shown.

There were other cases in which the whole cost of the extensions had been advanced to the firms, subject to payment of interest at 1 per cent. over bank-rate, with a minimum of 5 per cent. repayment being provided for within a comparatively short period from the termination of the period of control.

The Treasury criticised these arrangements. They doubted whether sufficient precautions had been taken to safeguard the public against loss in the case of certain very large advances, unless there was some other security than a lien on the extensions. Further, the Treasury called attention to the fact that "the magnitude of the operations had greatly exceeded the anticipations they had formed when the matter was brought to their notice for prior sanction at an earlier date," and the extension of the cost of the schemes from £4,000,000 to £19,000,000 should, in their opinion, have been regarded as "a new circumstance which merited report to them at an earlier stage." They asked what were the tangible results of these extensions.[1]

The reply of the Ministry (11 August, 1917), was to the effect that the output of ingot steel in Great Britain for the year 1916 had amounted to 9,245,457 tons, showing an increase of 894,513 tons over the 1915 output. Not less than 700,000 tons of this increase had been derived from extensions to steel works carried out under the Ministry programme, and if these extensions had not been made it would have been necessary to import the equivalent of this 700,000 tons in the form of finished steel from America at a cost of £13,340,000, involving an extra cost over production at home of about £8 per ton, or £4,640,000.

IV.—The Basic Steel Programme.

The schemes for the erection of new steel furnaces were considerably modified in the early part of 1917, with the inception of the home ore programme. A considerable number of furnaces planned for acid steel were actually altered and finished as basic furnaces. A further programme was arranged for the conversion of existing acid furnaces to the basic process.[2] In July, the building programme of the Iron and Steel Department had again to undergo revision in view of the enormous demands put forward by the Admiralty for ship plates and sections to meet the new merchant shipping scheme. Additional plate mills and supplementary extensions already in progress, which were to increase the weekly output of plates by 13,700 tons, became of the first importance, and extensions to rolling mills were given the highest general priority number. Firms were asked to make a return of their requirements, so that where progress was likely to be delayed by non-delivery of special parts, an emergency priority could be given.

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[1] 28 June, 1917. (94/Gen./2846.)

[2] Home Ore Supply Committee Report, 6.4.17. *Iron and Steel Industry*, 1914-1918, p. 42.

The Committee on the Increased Mercantile Shipping Programme further recommended that a scheme, abandoned at the end of 1916, for the erection of new rolling mills which would have a weekly output of 3,000 tons of ship's plates per week, should be proceeded with at once.[1]

V.—Financial Position in 1918.

The German offensive in the spring of 1918 made it specially important to maintain steel production at the highest possible level. Home production was to be kept up to the programme agreed upon for 1918, but the Iron and Steel Department suffered grave difficulties owing to the "clean-cut" policy adopted to meet the Army's need for men, which affected not only the steel and blast furnaces, but the labour needed for all extension schemes.[2] In August, 1918, when the Allies had begun their victorious offensive, the need for increased output of steel was less pressing and, in view of the scarcity of coal and labour, the question arose whether it was desirable to complete all the projected steel works extensions, especially in view of the fact that the munitions programme for 1919 called only for 10,000,000 tons of steel ingots. The Statistical Department reported on 1 July, 1918, that work to the value of £11,488,000 still remained to be done, on the various schemes for steel works, blast furnaces and other extensions,[3] but this figure was found to be considerably under estimated, and the Steel Department estimated the cost of the work still to be done at £20,514,772. The total expenditure sanctioned on steel works extensions up to 1 March, 1918, was £23,903,520, but, owing to the constant advances in wages and other increasing costs, it appeared probable that the estimates would be exceeded by more than £8,000,000, making a total of over £32,000,000.

This was a serious situation, but the Steel Department resisted proposals to stop all constructional work on steel extensions on the ground that, in many cases, the extensions were practically complete, and that compensation would have to be paid if the works in progress were not completed. Further, even if all the steel produced when the extensions were completed could not be used in Great Britain, it would be available for the Allies. The new works would be more efficient than older works, and by saving coal and labour would make the British industry more able to compete in the open market. On the other hand it was urged that there would probably not be sufficient labour and coal to work these extensions even if completed. Mr. Layton pointed out that the coal and labour situation was such that the maximum output that could be hoped for in 1919 was 10,000,000

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[1] C.R. 4414.

[2] Minutes of Co-ordinating Committee, 4.3.18, 23.4.18. (HIST. REC./R. 1000 61 ; C.I.S.P./Gen./47.)

[3] Minutes of Co-ordinating Committee, 2.8.18, 9.8.18.

tons instead of 12,000,000 tons, and on 28 September the Minister decided that the 1919 munitions programmes should be based on a home output of 9,500,000 ingot tons.[1]

From the financial point of view the position was serious, the cost of extensions being at the rate of £800,000 a week, and, taking the average of the agreements, the Government might be liable for about half of this sum. The Finance Department urged (19 and 23 September), that it was of vital importance that the Iron and Steel Department should report, as quickly as possible, which of the extension schemes could be abandoned. Even if labour and coal could be obtained to develop the full capacity of the extensions, the total output would not be required for war purposes. The works would not be able to earn the excess profits out of which the Government contribution to their cost was to be made, and the Government might have to meet the guarantee given against this contingency.[2] Moreover, the schemes appeared to have passed from a Ministry requirement to one of general trade policy, and the Finance Department were not empowered to sanction expenditure on future trade requirements.

Sir John Hunter was not prepared to admit that they were in any sense post-war schemes. The steel extensions, as sanctioned, were all devised to meet war requirements, as put forward by the War Office and Admiralty, and to make Great Britain independent of foreign steel supplies, especially of American supplies,[3] the original scheme for an output of 10,000,000 tons being increased to 12,000,000 tons when the shipping position became serious, at the urgent request of the Admiralty, though it was realised that certain of the extensions could not be completed until 1919. The bulk of the extensions would be finished by the end of 1918; they were due for completion under existing conditions as follows :—

	Extensions completed.	*Extensions to be completed by :—*			
		Dec., 1918	March, 1919	June, 1919	Sept., 1919
Steel Works Extensions ..	52	54	10	4	3
Wire Rod Mills	2	2	—	—	—
Blast Furnace Extensions ..	18	34	5	4	—
Coke Oven Extensions.. ..	1	1	—	1	—

[1] Minutes of Co-ordinating Committee, 2.8.18, 9.8.18, 20.8.18, 20.9.18, 27.9.18, 11.10.18.

[2] Minutes of Co-ordinating Committee, 20.9.18.

[3] Steel was being imported from America at the rate of 768,000 tons per annum, valued at £11,820,000, and pig iron at the rate of 720,000 tons per annum, valued at £4,600,000.

Sir John Hunter stated that the constructional labour employed on those schemes which were not expected to be completed by 31 December, 1918, amounted to 6,737 workmen, but that it must not be assumed that the stoppage of these schemes would automatically release this labour for constructional work in other districts, as the great bulk would be absorbed at once in the steel works themselves, and very little, if any, could be reckoned on as available for other building schemes. He thought, however, that one large steel works extension and one coke oven extension, both of which would probably not be completed until 1920, might be cancelled.

On 11 October, the Co-ordinating Committee agreed to the cancelling of these schemes and recommended that all the other extensions should be proceeded with without any war priority being given to the work, but that a sub-committee, representing the Finance and Steel Departments, should be formed to consider the continuation terms to be laid down in each case.[1] Sir Philip Henriques and Mr. Guedalla were appointed to serve on this committee, which reported (26 October) that the estimates of total expenditure had increased to £39,719,063. Of this sum £16,893,111 had been paid to contractors by June, 1918, and the cost of the extensions still to be carried out was estimated at £19,602,075.

The general question of the financial liability of the Ministry for the cost of the steel works extensions was a difficult one.[2] In a number of cases the Ministry had agreed to advance a certain proportion of the cost as originally estimated, and when the estimates were exceeded the question arose whether the Ministry was liable for the whole excess or only in the same proportion as it was liable under the original estimates.

Sir John Hunter thought that there was a binding formal contract between the Government and the steel makers, and that large claims for compensation would be put forward by the steel makers, who had spent vast sums of money and would probably be financially embarrassed by their unremunerative expenditure. If the steel makers were unable to earn excess profits the fault would not rest with them, and it must be recognised that in nearly all cases the Government had asked them to make these extensions. There was also a further liability in that most of the earlier agreements included a bonus on output amounting to as much as 37½ per cent. of the estimated cost. This was, however, a question for the Law Officers of the Crown. Sir John Hunter admitted that all the financial estimates of the cost of the schemes had been exceeded, owing to the increases in wages and in the price of materials, the cost being greater in the later than in the earlier extensions and amounting in many cases to 50 per cent. over the original estimates.

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[1] Minutes of Co-ordinating Committee, 11.10.18.

[2] Minutes of Co-ordinating Committee, 27.9.18, 2.10.18, 11.10.18.

A month later, while financial questions of this kind were still under discussion, the whole position was changed by the signing of the Armistice. It then became the policy of the Ministry to curtail outstanding extensions wherever possible, in order to limit its liability for contribution to the cost of schemes in which it was no longer directly interested. In most cases, however, in order to avoid waste of the money already spent, it was decided that the extensions must be completed, and at the end of March, 1919, £2,925,923 represented the value of work still to be done on uncompleted extensions.[1] It was later found possible, by agreement with certain of the firms, to commute the Ministry's liability to contribute a percentage of the total cost, by the payment of lump sums, the firms continuing the extensions without further supervision from the Ministry, but furnishing auditors' certificates of costs.[2]

The figures of total expenditure obtained when the financial settlement was nearly complete, showed that the total cost of some 365 schemes for increasing the production of steel, iron, and coke was approximately £45,524,303, of which the State contribution amounted to £23,556,742, or nearly one half. Inland Revenue allowances and writings off out of excess profits agreed upon by the Ministry, accounted for £13,612,348 of the State's contribution, while direct disbursements by the Ministry totalled £9,493,684. These extensions are grouped, according to the type of assistance given, as follows :—

(1) *Inland Revenue Cases.*—Cases in which the contribution was by writing off out of excess profits.

(2) *Irrecoverable Contribution Cases.*—Cases in which the Ministry contribution was accepted in lieu of Inland Revenue allowances.

(3) *Recoverable Contribution Cases.*—Cases in which the company concerned agreed to claim from the Inland Revenue Department, allowances at least equal to the Ministry contribution, and to refund to the Ministry these Inland Revenue allowances up to the amount of the contribution, together with a percentage of the excess.[3]

(4) *Whole Cost Contribution Cases.*—Cases in which the Ministry had borne the whole cost of the extensions, these remaining the property of the Department.

The relative importance of these groups together with a small group of cases in which, owing to the extensions having been undertaken

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[1] Sec./Gen./1308.

[2] D.S.P./A/41.

[3] This type of contribution was introduced from 6 November, 1917.

without Ministry supervision, the amount of the financial assistance afforded can only be approximately stated, appears from the following table :—

Expenditure on Extensions to Coke, Iron and Steel Works.[1]

	No. of Schemes.	No. of Firms Affected.	Estimated Cost.	Approved Expenditure or Ascertained Cost.	Government Contribution.
			£	£	£
Writing off out of Excess Profits.	144	76	17,953,562	25,739,026	13,612,348[2]
Irrecoverable Contributions.	58	48	5,793,900	8,986,830	3,862,982
Recoverable Contributions.	129	87	5,458,009	6,125,581	2,447,080
Whole Cost Contributions.	34	26	3,167,001	3,385,123	3,183,622
Miscellaneous Contributions.	—	—	—	1,287,743	450,710[2]
Total ..	365	237	32,372,472	45,524,303	23,556,742

[1] These figures must be taken as approximate and represent the position in September, 1921. For further details see Sec./Gen./1308.

[2] Inland Revenue allowance taken at an average of 35 per cent.

CHAPTER IV.

IMPORTS AND EXPORTS OF STEEL AND IRON.

I.—Imports from the United States and Canada.

In addition to the home production of steel and iron, there were considerable imports from North America and from Scandinavia. In the former case the imports consisted of materials which, if capacity, raw materials and labour had been well available, could have been provided as well and more cheaply in Great Britain. The Scandinavian materials stood apart, and had always been imported by the British steel industry on account of their special qualities. Though research showed that substitutes could be manufactured in England, it could be only at the expense of a diminished output of other classes of steel and iron.

Imports of shell steel from North America were first arranged for to meet the shortage during 1916. Purchases in the United States were made through the Government agent, Messrs. J. P. Morgan & Company, New York, who had been appointed before the Ministry of Munitions was established.[1] On 19 September, 1915, H.M. Consul-General at New York telegraphed to the Ministry that Canada could supply large quantities of shell steel without interfering with the output of shells and forgings. It was agreed that 250 tons should be sent as a sample, and, if it proved satisfactory, orders would be placed for steel, which would be inspected and pass the necessary tests before being shipped from Canada.[2] Messrs. Morgan were asked to make inquiries for 100,000 tons of shell steel in Canada, and their quotation was received on 12 November. In spite of the urgent representations made by the Director of Raw Materials the Treasury refused to place further orders in North America, but in February the shortage of steel was so serious that this decision was reversed.[3] Orders were placed with two Canadian firms, who were to begin shipments of 8 in. steel billets in April and May, 1916. On 1 August, however, no steel had arrived. The Imperial Munitions Board stated that one of the firms would begin shipments the following week of 2,500 tons, while another 9,000 tons of bars was waiting to be re-tested. The second firm, however, had to report serious delays in obtaining a satisfactory output.[4]

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[1] See Vol. II, Part III.
[2] Sir L. Llewelyn's Papers, 164. See also Vol. II, Part IV.
[3] Hist. Rec./R./1810/57.
[4] C.R. 4506.

At the same time that Messrs. Morgan had obtained the first Canadian quotation, they made inquiries for 100,000 tons of shell steel in the United States of America. On 21 February, 1916, however, the Ministry of Munitions asked for Treasury sanction for the purchase of 450,000 tons of shell steel in the United States and Canada. The quoted price of the United States steel, which would be for the manufacture of larger sized shells, was considerably above British shell steel, being about £18 per ton f.o.t. maker's works. The estimated expenditure was £8,000,000 at the rate of £1,000,000 a month, beginning in May, but even at the price quoted, which during the year, rose to £20, the purchase of shell steel would cost much less than the alternative purchase of shell. Treasury sanction was granted on 25 February on the understanding that the proposed order was not by way of re-insurance in the event of the failure of the efforts to increase British production.[1]

Considerable difficulty was experienced in the United States in obtaining satisfactory supplies, as the American steel works were not accustomed to making the class of steel required. In June, 1916, Mr. C. S. Atha went to the United States to discuss these technical difficulties. The manufacture of shell steel required greater attention to the details of melting, casting and rolling than was the case with ordinary commercial steel, and it was impossible in many American works to carry out the best methods of shell steel manufacture. A satisfactory class of steel, however, was ultimately produced in America.[2] Difficulties then arose over the tests required by the inspectors, which were much more stringent than those to which American manufacturers were accustomed. It was long before these difficulties were surmounted, and there were many complaints from British shell makers of the quality of American steel.[3] In July 14,000 shell steel billets had been passed, and the American production had reached about 1,800 tons a week. The Ministry, however, had been looking for the shipment of 5,000 tons per week in August.[4] Early in November billets were being delivered at an average rate of 8,000 tons per week.[5] In all, some 76,197 tons of shell steel were imported by the end of 1916 from North America.

The French Government were also purchasing shell steel in the States through Messrs. J. P. Morgan, but the French requirements of 120,000 tons for delivery before 31 December, 1916, could not be covered, as the steel works were becoming congested with orders as far forward as 1917. The Italians were purchasing separately, and in July, 1916, the Ministry were anxious to make arrangements to prevent competition between the Allies for the supplies required in 1917. Major Hausser, the French Government representative in London, suggested a scheme of joint buying but, pending a decision,

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[1] Sir L. Llewelyn's Papers, 164; HIST. REC./R./1810/57.
[2] *Iron and Steel Industry*, 1914-18, p. 10.
[3] See Vol. IX, Part II.
[4] HIST. REC./R./1810/43; C.R. 4507.
[5] C.R. 4508.

the Ministry suggested to him that arrangements should be made to purchase shell steel in common, as was already done in the case of copper.[1] It was agreed, in October, 1916, that a conference should be held at New York between the technical representatives of the three Allies, where the requirements of all for the next six months would be reviewed. No alterations would, however, be made by them until the whole question had been considered in London, where the new Inter-Allied Munitions Bureau would be the authority in future responsible for the co-ordination of all orders for steel in the United States.[2]

For delivery during the first six months of 1917, the British Government ordered 500,000 tons of shell steel, while the French ordered 1,100,000 tons, and a British purchase of 60,000 tons on behalf of the Italians was proposed. In addition, the British Government had placed orders for 17,700 tons of steel castings out of a further programme of 150,000 tons in the same period.[3] In December, 1916, however, owing to exchange difficulties, the Cabinet decided that purchases in the United States of America must be restricted, and the Minister ordered that every purchase was to be submitted for his approval before being sent to the Treasury for sanction. A small departmental committee was set up in order to scrutinize the proposed purchases.[4]

The Ministry of Munitions had encouraged private consumers to import steel, other than shell steel, on their own account. These purchases were too small to compete with direct Government purchases, and took the second place as regards shipping facilities from America. The sale of this imported steel was controlled by Order in Council dated 20 November, 1916, and it could only be sold for war purposes.[5]

With the increase in the merchant shipbuilding programme, the possibility of importing ship plates was considered. Negotiations were opened in Canada, but there was no supply of ship plates available in the United States and arrangements were made to press on the delivery of shell steel bought by the French Government, but lying at American ports awaiting shipment, instead of continuing deliveries of British shell steel to France, so that the manufacturing capacity thus set at liberty in Great Britain could be diverted to producing ship plates.

In 1917, over 500,000 tons of shell steel were imported,[6] and for the original 1918 programme the import of 1,000,000 tons was contemplated,[7] but was reduced to 500,000 tons in December, when the

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[1] C.R. 4508.
[2] C.R. 4506, 4508.
[3] C.R. 4508.
[4] *Ibid.*
[5] C.R. 4508.
[6] *Iron and Steel Industry*, 1914–18. Alloy steels for aircraft work were also imported in small quantities. (Printed) *Weekly Report*, No. 100, III (14.7.17).
[7] HIST. REC./R./1810/27.

programme was revised.[1] This meant that the ammunition available during 1918 would be much less than the requirements put forward by British Headquarters in France, and so serious did the position appear that the Ministry asked for Treasury sanction for the purchase of 800,000 tons, in order to be prepared for any general improvement in the shipping situation and for unexpected opportunities for shipping steel. The Treasury referred the matter to the American Board, which refused to sanction the further purchase, although the United States authorities had already assigned provisionally 750,000 tons of shell steel to Great Britain.[2] As the Ministry had foreseen, the actual shipments in the first half of 1918 were much greater than the tonnage allocated by the Shipping Controller. In the first six months of 1918, 443,302 tons of shell steel were delivered in Great Britain: besides a small amount of general steel,[3] and some special steels for aircraft work.

American shell steel, as imported, was not broken into shell lengths, and it was necessary to erect billet-breaking plants to deal with the material before it was delivered to the shell factories. The chief of these was at Trafford Park, Manchester, on the Ship Canal, and was under the direct management of the Ministry of Munitions. Similar plants, which covered an area of 45 acres, were established at the Wolverhampton Corrugated Iron Company's works, Ellesmere Port; the Great Eastern Railway Company's works at Stratford, and at the National Projectile Factory, Lancaster. These plants together handled an average of 14,000 tons of imported steel weekly, of which one half was broken at Trafford Park.[4] Separate arrangements were made in Scotland, where about 1,000 tons of imported steel was broken and forged by various firms. At Fazakerley arrangements were made for storing and sorting billets, for delivery to factories which could do some breaking but had no storing accommodation.[5]

II.—Imports from Scandinavia.

The safeguarding of the supply of Swedish pig iron, bar iron and steel was considered early in 1915, the Sheffield steel makers pointing out the difficulties which a shortage of these materials would create, in the manufacture of high speed tool steel, carbon steel and other Sheffield products. Conferences were held in April and June, 1915, with representatatives of steel makers using these materials,[6] while in August the Foreign Office intimated that the Swedish position was critical.[7] It was agreed that stocks should be acquired[8] and

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[1] D.M.R.S. 595.
[2] HIST. REC./R./1810/32, 30.
[3] D.M.R.S. 595.
[4] Vol. VIII, Part II, Chap. IX.
[5] C.R. 4507; C.I.S.P./Dep./53A.
[6] *Iron and Steel Industry*, 1914–18, p. 33.
[7] Sir L. Llewelyn's Papers, 288.
[8] C.R. 1890.

Mr. Albert Senior, of the firm of Messrs. George Senior & Sons, was sent in July on a mission to Sweden to buy stocks of Swedish iron and steel, the purchases being financed by the Ministry of Munitions through the firm of Messrs. C. J. Hambro & Son, acting as government agents. By August, Mr. Senior had purchased 20,000 tons of pig iron and was considering further offers, but steel was more difficult to obtain. In all, however, he purchased during his mission 150,000 tons of Swedish material at very advantageous prices.[1]

Buying by the Ministry through Messrs. C. J. Hambro & Son was continued during 1916, and contracts were placed for the following Swedish materials :—

Pig Iron	165,000 tons
Bar Iron	30,000 ,,
Steel	43,000 ,,
Steel Scrap	3,000 ,,

Private firms were also encouraged to lay in stocks on their own account, and in May, 1916, stocks of Swedish steel and iron equal to six months' requirements were held.[2]

In October, 1917, the annual requirements were stated as follows :—

Pig Iron	120,000 tons
Bar Iron	30,000 ,,
Steel	50,000 ,,
Steel Scrap	10,000 ,,

The iron position was satisfactory, there being 10 months' supply of pig iron and 7 months of bar iron, but stocks of steel and scrap were very low, only one and three-quarters months' supply of steel and one and a half of scrap being held in Great Britain. The political situation was again precarious, while there were considerable balances under Swedish contracts due both to the Ministry of Munitions and to traders[3] :—

	Pig Iron.	Bar Iron.	Steel.	Scrap.
	Tons.	Tons.	Tons.	Tons.
Trade	62,609	10,888	795	12,679
Ministry of Munitions	41,464	9,884	—	3,061
Total	104,073	20,772	795	15,740

During the year, 1917 98,500 tons of pig iron were actually imported from Sweden, while in the reduced iron and steel programme for 1918, only 100,000 tons were required.[4] Owing to the fall in the Swedish exchange, the Treasury pressed the Ministry to reduce these

[1] HIST. REC./R./1810/64 and 8.
[2] Sir L. Llewelyn's Papers, 367.
[3] *Ibid.*, 288.
[4] D.M.R.S. 595.

purchases (31 May, 21 June, 1918). Swedish bar iron was, however, essential, and after the signature of the commercial agreement with Sweden, the Treasury agreed that £50,000 a month out of the kroner credit provided under that agreement should be used for these essential imports, the Ministry undertaking to sell ferro-manganese directly with a view to supporting the exchange.[1]

III.—Supplies to the Allies.[2]

Before the formation of the Ministry of Munitions, the French Government had an organisation in London, under Major Hausser, which placed contracts in Great Britain, with the assistance of Mr. MacLellan, who continued this work after the formation of the Ministry of Munitions until the end of the war. From October, 1914, to June, 1915, the French had obtained 120,000 tons of steel in Great Britain. At a meeting between the steel makers, the French Commission and Sir L. Llewelyn (29 June, 1915), the contracts for the third quarter of 1915 were adjusted for 89,750 tons, and new contracts were placed for the fourth quarter for 123,900 tons. If possible, the arrears of 16,000 tons were to be made up, and a further 17,500 tons contracted for. No formal agreement was made during the war as to the supply of shell steel to the French Government, but at a conference on 25 June, 1915, it was decided that all supplies of steel for the French Government should be arranged in conjunction with the Steel Department, controlled by Colonel Wright.[3] The contracts continued to be made between the French Government and each British manufacturer.

The British steel makers found even more difficulty in working to the French than to the British shell steel specification, and by August, 1915, the contracts were very much behind. At the end of October, a French commission came to England and visited steel works which were manufacturing French shell steel or were prospective manufacturers. Modifications were arranged in the specification, and advice on methods of manufacture was given by representatives of the French armament firms, while contracts at the rate of 1,000,000 tons per annum were arranged for 1916.[4]

On 14 March, 1917, the Ministry of Munitions undertook to supply between 40,000 and 48,000 tons of shell steel a month for French requirements. Further negotiations took place in the summer of 1917, in connection with the reductions in the British shell steel programme, and it was arranged (12 September, 1917) that the Steel Department was by the end of October to stop rolling 75 mm., 82 mm. and 145 mm. bars for the French Government in England, and arrange instead for the shipment in British ships of 500,000 tons of American

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[1] C.R.V./S./0555.
[2] See also Vol. II, Part VIII.
[3] Sir L. Llewelyn's Papers, 19.
[4] *Ibid.*

shell steel belonging to the French Government, but lying at American ports, at the rate of 50,000 tons per month.[1] The supply of 1,500 tons a week of steel for gaines, due to be shipped to France from England, was to continue. French demands for steel, however, continued to increase, and at a conference held in Paris on 17 September, 1917, the French requirements were stated to be 88,305 tons a month, while the Ministry of Munitions could only allocate 39,450 tons.[2]

When the 1918 programme was cut down in December, 1917, in accordance with the recommendation of the Restriction of Imports Committee, the allocation of shell steel to France was reduced to 11,500 tons a month, and when the second " cut " in munitions supplies was made in the following February, the Ministry of Munitions decided that it was impossible to supply France with any shell steel after the end of that month,[3] while the supply of hematite pig iron was to be halved. Shell steel, however, continued to be supplied on a reduced scale averaging about 10,000 tons a month until the end of the war.[4] The export of special steels, such as steel for gaines, boiler plates, tin plate, spring steel, and armour plate for tanks, which was essential to France, was also continued.[5]

Shell steel was also supplied to Italy on her entry into the war in 1916, and contracts for the supply of 3,000 tons a week were made in Great Britain, in addition to steel supplied for the manufacture of Italian shell in Great Britain. In April, 1917, these contracts were practically at an end, but the British Government had promised to continue the supply if possible, and existing contracts for 10,000 tons of 6 in. shell steel a month were continued. At the Rome conference of January, 1917, the British Government had agreed to supply a total quantity of 23,000 tons of shell forgings and shell during the first quarter of 1917. In September, the Italians asked for 14,000 tons a month for the last four months of the year.[6] After the disaster at Caporetto, allocations to Italy were increased ; Great Britain agreed to supply 18,000 tons a month in the first half of the year, and in the second half 20,000 tons a month, in order to meet the increased demands for shell put forward by the Italian General Staff, to replace their heavy losses of guns and ammunition.[7] This increase could not be carried out, and when the second of the drastic reductions in the steel programme was made in February, 1918, it became necessary to give notice to the Italian Ministry of Munitions that the monthly shipment of 14,000 tons of shell steel could not be continued after the end of June, 1918, in face of the shortage of shipping, and that equivalent steel must be obtained in America.[8] It was found possible, however, to continue supply on a reduced scale averaging about 7,000 tons a month.[9]

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[1] M.C. 6 ; D.M.R.S./A.S./92. This shipment had to be temporarily reduced in the early part of 1918, owing to the shipping crisis.

[2] Hist. Rec./R./1810/78.

[3] D.M.R.S. 595.

[4] Hist. Rec./R./1000/95, p. 69.

[5] D.M.R.S. 595.

[6] Hist. Rec./R./1811/2.

[7] Hist. Rec./R./1811.2/1.

[8] D.M.R.S. 595.

[9] Hist. Rec./R/1000/95.

In the summer of 1918, a considerable amount of steel plates and sections were supplied to Italy by the Admiralty for shipbuilding out of their own steel allocation, as the material could be more usefully and earlier employed for ship construction and repair in Italy than in the United Kingdom.[1]

During 1916 and 1917, Great Britain supplied a large quantity of hematite pig iron to her Allies, and efforts were made to replace it to a certain extent by importing basic pig iron from the United States of America. In 1917, 125,000 tons of pig iron were actually imported on contracts for 150,000 tons to be delivered up to June, 1918. In the following year, 180,000 tons of basic pig iron were purchased for delivery during the second half of 1918 at the cost of nearly $5,000,000.[2] In September, a further purchase of 100,000 tons was under consideration, but actually, at that time, only 4,681 tons had been shipped, and quicker delivery was urgently needed. For 1919, a much larger purchase was proposed. The arrangements for substituting direct imports of steel from America into France and Italy in place of importation from Great Britain, which had been adopted in 1917, were not found to be possible in the case of pig iron. The material available for export in the United States was practically all basic iron, which could not be used in the acid steel furnaces of France and Italy, nor was it suitable for all the classes of steel which they required. Great Britain, therefore, agreed to continue supplying hematite pig iron from Great Britain, an equivalent amount of 500,000 tons of basic pig iron being supplied to this country by the United States.[3]

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[1] D.M.R.S., 465D; C.R.V./I./067. The Treasury strongly deprecated supplies which needed replacement directly or indirectly from U.S.A. being made. See Vol. II, Part VIII.

[2] M.C. 241, 271.

[3] D.M.R.S., 595; HIST. REC./H./661/4.

CHAPTER V.

STEEL AND IRON SCRAP, FERRO-ALLOYS AND MISCELLANEOUS MATERIALS.

I.—Steel and Iron Scrap.

The increasing use of steel scrap in steel manufacture is a feature of the war period. Before the war the total consumption of steel scrap by steel makers probably did not exceed 30 per cent. of the charge, and in many cases it was as low as 10 to 15 per cent.[1] The shortage of pig iron made it essential to use as large a proportion of scrap as possible; the Iron and Steel Department put pressure upon the steel makers to work with 50 per cent. of scrap, and the Gun Ammunition Department experimented with briquetting plants to make the scrap more readily usable. On 7 July, 1916, steel scrap was controlled and prices were fixed.[2] An advisory committee, composed of representatives of the chief scrap merchants, was set up. The scrap merchants had previously been middlemen coming between the producer and the consumer, and their business being largely speculative, the fixing of maximum prices was a serious difficulty.

The greatly increased volume of steel scrap in the form of shell turnings that resulted from the large scale manufacture of gun ammunition was at first used in blast furnaces for the production of pig iron, but as steel makers became accustomed to the use of a large proportion of scrap, steel furnaces began to compete with blast furnaces for steel scrap of all kinds. Several sources of scrap available in normal times—ship-breaking, old railway stock, and the breaking up of obsolete plant—were unproductive during the war, and special measures had to be taken to maintain supply.[3]

The subject was considered by the Metals and Materials Economy Committee and by the Advisory Committee of the Ministry between November 1916 and January 1917.[4] From the beginning of 1917 onwards the Iron and Steel Department took over the whole responsibility, previously shared with the Shell Manufacturing Department for the collection and transport of steel scrap, defective forgings, etc., national factories and other shell makers sending their scrap to the nearest steel works as directed by the department. Sales were no longer to be made to dealers except in cases where the material had to be collected in small quantities.[5]

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[1] *Iron and Steel Industry*, 1914–1918, p. 32.
[2] See below, p. 104.
[3] C.I.S.P./Gen./526.
[4] A.C. 179; M.C. 383; D.M.R.S. 540M.
[5] C.I.S.P./Gen./526.

On 20 February, 1917, Mr. Alexander Walker was appointed Director of Scrap Metals,[1] and his branch, helped by the Salvage and Central Stores Department, and working through the scrap metal trade, collected and brought into the market dormant munitions and commercial scrap. The Admiralty and War Office assisted by releasing scrap materials in dockyards or in the custody of the Home Commands, and by bringing salvage from the battlefields in France.

Six months later (28 August, 1917), Mr. Walker reported that the large accumulations of ferrous scrap had been utilised through the assistance given by the Area Engineers, and a local organisation had been set up to obtain scrap from railway companies, collieries, etc.[2]

Each steel maker was required to make returns of the amount of pig iron and scrap he used each month, and the makers who were using a very small proportion of scrap were dealt with individually, with the result that the average consumption of scrap was raised from 34 to 47 per cent. of the charge, which represented a saving of 750,000 tons of pig iron annually.

By the use of a de-tinning process a valuable source of supply was opened up, which it was estimated might ultimately yield at the rate of 100,000 tons a year. The decision to convert into chemical shell most of the defective shell that had accumulated reduced the amount of scrap to be obtained from this source, but the amount of ferrous scrap recovered from France amounted to about 6,000 tons a week.[3] The Ministry decided that no useful purpose would be served by organising a house to house collection of domestic scrap and this was left to local economy committees.

One of the chief problems was to increase the amount of oxygen allocated to the scrap metal trade, as the oxy-acetylene process was much used in breaking up heavy steel and iron scrap. Only about 50,000 tons a year were being broken up in 1917, though it was estimated that if enough oxygen were available 250,000 tons could be broken up in 1918.[4] The shortage of scrap was very serious in the spring of 1918, especially in South Wales, as the fixed allowance of 10s. per ton for carriage prevented the South Wales steelmakers obtaining scrap in competition with firms nearer the chief centres of production. A special carriage allowance was therefore made, as several South Wales works were standing idle for lack of scrap. The use of steel turnings in blast furnaces, which was at the rate of 50,000 tons a month, was controlled, the use in basic furnaces being reduced in order to save scrap for acid furnaces and steel works, and better priority in transit was obtained. A scheme for acquiring dormant scrap by compulsion and for purchasing obsolete plant for scrap purposes was adopted on 9 May.[5]

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[1] General Office Notice, No. 101.

[2] HIST. REC./R./1800/39.

[3] Report of Council Committee, 19 October, 1917. (M.C. 54). Arrangements were also made to sell steel, iron and tinned scrap to the French Government, February, 1918 (C.I.S.P./Gen./526).

[4] C.I.S.P./Gen./526.

[5] C.I.S.P./Gen./526.

II.—Ferro-Alloys.

(*a*) Ferro-Silicon.

In July, 1915, steel manufacturers were circularised by the Ministry of Munitions on the supply of ferro-silicon, but in no case was any shortage anticipated in their answers. Some low grade ferro-silicon was manufactured in Great Britain, but practically the whole of the high grade material, with 80/90 per cent. basis, was imported from France, from the Société Commercial de Carbure et de Produits Chimiques, Paris, the syndicate which controlled the French works. Large quantities of high and low grade ferro-silicon arrived in this country from France in July, but on 25 August, 1915, Messrs. Ridge, Beedle & Company, of Glasgow, the British agents of the French syndicate, notified the Ministry of Munitions that only half the quantity to be delivered against contracts could be delivered in future. Early in the year the syndicate had applied to the French Government for more labour, but nothing was done until August, and it was then too late to increase supplies as the electric furnaces of the silicon works were dependent on water power from the Alps, which was greatest in the early summer. Representations on the subject had been made by Mr. Lloyd George at the conference held at Calais in June with M. Thomas, but when workmen were supplied in August the season was over and no output could take place till the following summer. In consequence most of the silicon works were turned over to other munition work, and in view of the increased needs for ferro-silicon in France, Major Hausser informed the Ministry of Munitions on 23 September that export of ferro-silicon from France had been prohibited.

In the meantime, to meet the prospective decrease of imports, Messrs. Ridge, Beedle & Company were asked to enquire for ferro-silicon in Norway. They were offered 300 tons of 45 per cent. ferro-silicon at £17 2s. 6d. a ton c.i.f. Manchester. This was an advance of £4 a ton over the pre-war price, but on 7 December it was decided to accept the offer of the Norwegian works, and the 300 tons were allocated to various steel makers.

This supply, however, was not sufficient when the French imports were entirely cut off, and Mr. Beedle was instructed to go to Switzerland to purchase over the year 10,000 tons of ferro-silicon at a price not exceeding £18 f.o.t., at the Swiss works for 45 per cent. ferro-silicon with the usual variations in price for lower and higher grades. As far as possible, Messrs. Ridge, Beedle & Company, were to finance the purchase, with assistance from the Government if necessary. On entering into negotiations with the Meteor Company, it appeared that their whole output had been offered to the French Government, who had the option, if they did not require the ferro-silicon, of purchasing from 250 to 300 tons per month for the British Government. The Ministry had also obtained an option of regular monthly supplies from the United States of America of 400 tons, basis 45 per cent., deliveries to begin in December, 1915. It was decided to ask the

French Government to accept the offer of the Meteor Company and, if possible, reserve for the British Government 100 tons a month at the same price which had been paid to the Meteor Company. The Ministry of Munitions in return would help the Swiss company with supplies of coke and other materials. The option in the United States was also accepted[1] and a contract was placed for 4,000 tons of 45 per cent. ferro-silicon. A Liverpool firm were appointed Government agents for the import and distribution of this ferro-silicon and the supplies obtained through the French Government.[2]

These arrangements worked satisfactorily, and at the end of May, 1916, the stocks held by the steel makers covered on an average a period of two months. Other contracts were placed in the United States, and in August, 1917, imports were arriving at a rate of 1,500 tons per month.[3] In November, 1917, the supplies of high grade 90 per cent. ferro-silicon, needed by the Air Board, were short. To meet this demand, the Steel Department cancelled orders placed in America for 5,000 tons of low grade ferro-silicon, and obtained high grade material instead. An order was also placed in Norway for 3,000 tons of low grade ferro-silicon.[4]

(*b*) FERRO-CHROME.

In August, 1914, stocks of ferro-chrome in England were low, but, during the next six months, supplies, which were mostly derived from France, came regularly. In this period, the 10 firms using ferro-chrome had obtained 4,023 tons from France, 1,370 tons from Norway and 763 tons from British sources, a total of 6,156 tons. In the same period they had used 3,976 tons. In England, in June, 1915, the Newcastle Alloys Company was the only firm manufacturing ferro-chrome regularly. With one large furnace, their output was 40 tons a week. The Thermo Electric Company, Luton, was also able to produce it, and another firm could probably do so, but it was thought by the Board of Trade that in view of the satisfactory rate of import, it was unnecessary to erect a large ferro-chrome plant. Steel firms had been told to make arrangements for the rest of the year, and some had covered their requirements for the whole of 1916 as well.[5]

The use of ferro-chrome increased rapidly in 1917, owing to the aircraft requirements of alloy steel. A sub-committee of the Council Committee on the 1918 Programme was appointed in September to consider methods of meeting the shortage. The requirements of ferro-chrome were then estimated at 450 tons a month, rising in

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[1] HIST. REC./R./1810/18.
[2] *Ibid* and *Iron and Steel Industry*, 1914–18, p. 20.
[3] C.R. 4368.
[4] *Iron and Steel Industry*, 1914–18, p. 29-30.
[5] Sir L. Llewelyn's Papers, 2.

1918 to 850 tons a month. The contracts already placed provided for a monthly supply of 690 tons—340 tons from Norway, 190 tons from France and 160 tons from British works. The French supplies were very precarious, as only 37 tons a month were guaranteed absolutely, a *quid pro quo* being required for the rest. To provide the monthly rate of 190 tons, France needed from Great Britain 240 tons of carbide and 150 tons of ferro-silicon to make up for the capacity absorbed in ferro-chrome manufacture. Arrangements had been made to increase the home capacity for the production of ferro-chrome to 285 tons a month, and when this was attained, allowing for diminished imports from France, a supply of 702 tons monthly would be available. There was also a stock of 1,557 tons in the country, while 3,800 tons of chrome ore were in stock in Norway and 1,200 tons in transit. The ferro-chrome manufacturers in England also received 2,500 tons of Rhodesian ore monthly, which would produce 950 tons of ferro-chrome.[1] At this time (October, 1917) the shipping losses from submarines were very severe, and there was a possibility of losing the Norwegian supplies. Economies were effected by using scrap from chrome steel, and efforts were made to increase the home output.[2] The Newcastle Alloys Company's output could be increased from 200 tons per month to 350 tons in February, 1918, and to 600 tons after June, 1918, but it was felt by the Sub-Committee on Alloy Steel to be dangerous to concentrate the chief output at Newcastle. A report on a site and furnaces to be erected at King's Dock, Swansea, where there was available power to produce 300 tons a month, was asked for by the Sub-Committee, and the development of the Newcastle works deferred until this report had been received. In the meantime, the Thermo-Electric Company, Luton, were instructed to put all available power into the manufacture of low carbon ferro-chrome to produce 70 tons a month.[3]

(*c*) FERRO-MANGANESE.

Very shortly after the formation of the Ministry of Munitions, the alloy steel manufacturers were asked for returns of their requirements of ferro-manganese, and it appeared that the total amount used by them—80,000 tons annually—was approximately equal to the yearly output by the ferro-manganese manufacturers.[4] The alloy was manufactured in blast furnaces from high grade ore, imported during the war from India, but, in addition, a large quantity of low grade ferro-manganese or spiegeleisen was used as a "killer" of steel, the raw material used in its manufacture being the manganiferous ores chiefly coming from Spain. A sufficient supply of ferro-manganese was essential to British steel makers, while the export of steel from Sweden depended upon supplies of ferro-manganese from the United Kingdom.[5]

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[1] C.R. 4368.
[2] HIST.REC./R./1810/78.
[3] *Ibid.*
[4] HIST. REC./R./1810/18.
[5] For an account of the negotiations with the Foreign Office about the export of ferro-manganese, see Vol. VII, Part I; HIST. REC./H./1810/6.

At a meeting with manufacturers of ferro-manganese (12 June, 1915), it was arranged that the steel makers should keep a stock of 20,000 tons or the equivalent of three months' requirements; that the Associated Ferro-Manganese Makers should keep a stock of ferro-manganese equal to their sales in three months, and, in addition, a stock of ore equal to three months' sales of ferro-manganese, the figures in both cases being based on pre-war sales. By this arrangement they stocked 30,000 tons, or sufficient to meet the steel makers' requirements for six months. In addition one company was to keep a stock of ferro-manganese and ore to cover their pre-war sales over a period of six months, *i.e.*, 10,000 tons. The price at which ferro-manganese was sold to the steel makers was at the same time raised from £17 to £20 a ton in view of the increased freight rates for ore. These arrangements worked satisfactorily, and the stocks in the country in the first half of 1916 rose considerably above the amounts fixed. In the first four months, instead of the 60,000 tons agreed upon, there were each month over 90,000 tons in stock. In February, 1916, in view of freights having doubled since the price was last fixed, the price was raised to £25 on the understanding that if freights were lowered, the price would be lowered in proportion.[1]

At the beginning of 1917, the falling off of ore imports foreshadowed a shortage in the supplies of ferro-manganese, and, at a meeting of the Advisory Committee on 9 February, 1917, it was decided that the manufacture of special commercial steel, in which ferro-manganese was used to give long wearing properties, should be discontinued, and the use of substitutes should be investigated. Immediate relief, however, could only be attained by cutting off the exports of ore to the United States of America, which amounted to 6,000 tons a month, and by drawing on the stocks of ferro-manganese and ore in Great Britain, which were then equivalent to 113,000 tons of ferro-manganese.[2]

The position grew more serious and on 12 July, 1917, the ferro-manganese makers reported that their stocks of ore were only sufficient for six weeks' manufacture. Mr. MacLellan stated that Indian shipments, which were normally 45,000 tons a month, had been reduced by the Shipping Priority Committee for June, July and August to 25,000 tons a month. The reduction, however, had actually taken effect since March and in June only 12,650 tons had been shipped. At a meeting of the ferro-manganese makers, held in July, 1917, the supply of ore for the increasing number of basic steel furnaces was discussed. It was decided that the ferro-manganese makers should remain the sole importers of ore, but that the cargoes should be sent to centres suitable for quick distribution to the steel furnaces.

In January, 1918, the price was raised to £26 10s. a ton. During the remaining months of the war, although stocks could not be maintained at the level originally planned, the supply of ferro-manganese

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[1] HIST. REC./R./1810/18.
[2] A.C. 68.

was sufficient for home needs and for export to the Allies and to the United States of America, Norway and Sweden, which were dependent on the United Kingdom to a considerable extent for the ferro-manganese used in the steel exported for war purposes to the Allies.[1]

(*d*) Ferro-Vanadium.

Great Britain was entirely dependent on the United States of America for the supply of ferro-vanadium, which was practically controlled by two firms. All supplies were bought directly by the consumers. Stocks were in a satisfactory position in October, 1917, when the Sub-Committee on Alloy Steel was considering the requirements for the new steel programme. In August and September, 48 and 38 tons had, respectively, been consumed, while the stocks at the end of the same months had been 186 and 163 tons. If the new demands necessitated consumption of some 50 to 60 tons per month, there were sufficient stocks to cover a three months' demand.[2] It was decided that, in order to make the position secure, the Ministry of Munitions should acquire a stock of 100 tons of ferro-vanadium.[3]

(*e*) Ferro-Tungsten.

Supplies of ferro-tungsten and tungsten powder were the most difficult of all the alloys to secure at the beginning of the war, owing to the control of tungsten and wolfram ore having been in German hands before the war. Practically the only manufacturers of ferro-tungsten in Great Britain in August, 1914, were the Thermo Electric Ore Reduction Corporation, Ltd., and the Continuous Reaction Company, Ltd. The former company showed great foresight in contracting for a considerable time ahead for supplies of ore from the producers, who would otherwise have closed down. Both companies increased their output and two other firms, whose tungsten works had been closed down, re-opened them to meet the increased demands for British tungsten products.[4] Until the spring of 1915, these firms were able to meet the demands of the steel makers, but their output was limited by the shortage of wolfram ore, which was rising rapidly in price.

At a meeting of tungsten manufacturers held at the Admiralty on 14 July, 1915, it was decided to form a Wolfram Committee, of which the Chairman was Admiral Sir Edmund Slade. The Ministry of Munitions was represented while the other members were manufacturers and the committee worked to secure an increased output of ore and to fix prices. With the latter object it was agreed that the Government should become the sole purchaser of wolfram ore, acting through

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[1] *Iron and Steel Industry*, 1914–18, pp. 30, 31; C.R. 4368.
[2] Hist. Rec./R./1810/78.
[3] M.C. 99.
[4] Sir L. Llewelyn's Papers, 20a.

a Liverpool firm, who became the Government brokers and with whom the tungsten manufacturers placed their ore contracts. Existing contracts for ore were to remain valid if made before 31 August, 1915, but otherwise all ore was to be requisitioned by the Government and redistributed to firms of tungsten manufacturers, who were approved by the Ministry of Munitions. These firms received ore in proportion to their requirements based on the actual output shown by their returns.[1] The requirements of tungsten were estimated at 250 tons a month for Great Britain and her Allies, excluding France, but the output in July, 1915, was only 175 tons. Several other firms had put up plant for manufacturing ferro-tungsten and tungsten powder, and an increasing output was expected in the last half of the year, reaching 355 tons in December.[2]

The supply of tungsten products to the steel makers was also considered by the Wolfram Committee and at the suggestion of the high speed steel manufacturers, a system was initiated in September, 1915, under which firms of steel manufacturers were allowed to enter into contracts with the tungsten manufacturers for fixed quantities of tungsten products for definite periods at a fixed price.[3]

In November, 1915, contracts had been placed up to the end of August, 1916, for 2,618 tons of ferro-tungsten and tungsten powder.[4] At the end of twelve months it was found that certain Sheffield steel firms could not satisfactorily deal with all the tungsten they were receiving, and while there was a congestion of material at these works other steel manufacturers were short of tungsten.[5] In consequence, after various conferences, it was decided that the allocation of tungsten products should be taken over by the Ministry of Munitions. The firms were informed of this decision (23 August, 1916) and all contracts for ferro-tungsten and tungsten powder made before 1 September, 1915, were cancelled. The allocation to the steel manufacturers was made by a sub-committee of the High Speed Steel Committee and was based on the average monthly output of the various tungsten works for the period from January to June, 1916, which then amounted to over 226 tons. Certain quantities were, however, to be reserved in order to comply with existing contracts with certain firms for supplies to the Allies, viz., 25 tons of ferro-tungsten monthly to Russia, 5 tons monthly to Italy, and also 5 tons monthly to Canada.[6] The output did not in 1916 equal the requirements of the programme put forward for the supply of 20,000 tons of finished tool steel, but this was due to a shortage in the wolfram ore supplies, as the tungsten works in January, 1917, were only working to 45 per cent. of their capacity.[7]

A new difficulty arose during 1917, as complaints were received from the steel manufacturers about the quality of the tungsten received from the smelters, several of whom had only recently started producing.

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[1] Sir L. Llewelyn's Papers, 2A.
[2] *Ibid.*, 2.
[3] Sir L. Llewelyn's Papers, 2A.
[4] *Ibid.*, 2.
[5] *Ibid.*, 2A.
[6] M.C. 1064.
[7] Sir L. Llewelyn's Papers, 20A.

In May, Dr. Harbord and other officials of the Ministry of Munitions inspected the works of the complaining firms, but it was found impossible to fix the responsibility for the faulty steel.[1] Arrangements were therefore made for the analysis of all tungsten products used in steel manufacture, but in the meantime conferences were held with the manufacturers (August and September, 1917) to consider improvements in manufacturing methods. Finally decisions were arrived at fixing the specification of the ore to be supplied to the ferro-tungsten manufacturers, and the specification of the tungsten products to be supplied to the steel makers; the tungsten recovery efficiency was fixed as follows:—tungsten powder, 88½ per cent.; ferro-tungsten (electric process), 87 per cent., and ferro-tungsten (aluminium process), 91½ per cent.[2] A government analyst was appointed on 3 August, who visited all the works once a week to sample and analyse the week's output.[3] These arrangements necessitated a closer control of the industry, and on 30 November, 1917, an order was issued applying Regulation 30A of the Defence of the Realm Regulations to tungsten ores and metal. Under this order the Ministry took over the control of the wolfram supplies, which were still distributed under the original arrangement made in 1915, and allocated them amongst the tungsten manufacturers.[4]

These arrangements continued to work satisfactorily during the following winter, but in the spring the demand for tungsten fell off. The output of tool steel had fallen short of the programme and had never exceeded between 14,000 and 15,000 tons of finished steel, and in consequence the tungsten smelters had a considerable accumulation of supplies at their works.[5] A committee on the control of wolfram supplies was appointed to consider the situation. This was complicated by the fact that one tungsten-making company had been formed and was controlled by a group of Sheffield manufacturers, who obtained their supplies of tungsten from these works. The balance of the steel makers' orders for tungsten was divided amongst the other tungsten smelters. This plan had worked satisfactorily during the shortage, but placed the other firms at a considerable disadvantage when the demand had fallen, and complaints were made that a monopoly was being created.

The committee recommended that only sufficient wolfram ore should be allocated to meet the reduced demands for tungsten, the surplus being held at the cost of the Ministry as a Government reserve. The allocation of tungsten to steel makers was to cease, the manufacturers making their own arrangements with their customers up to the amount of their respective allocation of ore. The maximum price was, however, to remain fixed and the specification was to be complied

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[1] Sir L. Llewelyn's Papers, 545; C.I.S.P./Gen./347.
[2] *Ibid.*, 545.
[3] *Ibid.*
[4] M.C. 1064.
[5] *Ibid.*

with strictly by all firms. The question also arose as to the liability which might lie on the Ministry in connection with the allocation scheme under the Ministry letter of 23 August, 1916, as there was some doubt whether the Order of November, 1917, had completely superseded the first arrangement, and steps to relieve the Ministry were taken in conjunction with the Legal Department of the Ministry.[1] As a result arrangements were made for taking over the stocks of ore and tungsten products which remained on the manufacturers' hands on 9 April, 1919.[2]

III.—Limestone.

The limestone for fluxing, used in blast furnaces, was entirely obtained in Great Britain, being mainly quarried in the Weardale Valley, Durham, in Yorkshire, Derbyshire, Cumberland and Lancashire and also in South Wales. In the first two years of the war supplies were available to meet requirements, but only at the expense of depleting the stocks held by the iron masters. Owing to enlistment, output had diminished and transport was scarce, so that there was no surplus to meet the needs of the blast furnace extensions arranged during 1916 which brought the total requirements up to 20,746 tons a week.[3] In August, 1916, the position was serious, especially on the North-East Coast, which absorbed nearly half the limestone used; the ironmasters had 70,000 tons less in stock than they considered was needed for the furnaces actually in blast and output of limestone always decreased in the winter.[4] With a view to increasing the output, Mr. Merricks inspected various limestone quarries and as a result of his report, the Ministry of Munitions took over several quarries and arranged for the introduction of prisoners of war to work them. By the end of the year 1,500 prisoners were employed. In all, seven limestone quarries in the Buxton District of Derbyshire and four limestone quarries in Weardale were taken over by the Ministry. Camps were also erected for the prisoners' accommodation.[5]

The requirements of limestone were greatly increased by the basic iron programme initiated early in 1917. The Resident Engineers, appointed by the Home Ore Supply Committee in the chief iron ore districts, were made responsible also for the output of limestone. In May sufficient supplies were maintained from the quarries to meet the needs of the furnaces which were then being put into blast, and in July a stock of 125,000 tons had been accumulated in Cumberland and 20,000 in Durham, as a reserve for the winter.[6] In 1918, limestone was consumed in the blast furnaces at the rate of 4,500,000 tons per annum.[7]

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[1] M.C. 1064.
[2] Sir L. Llewelyn's Papers, 2A.
[3] HIST. REC./R./1810/5; C.R. 4506.
[4] C.R. 4507.
[5] *Iron and Steel Industry*, 1914–18, p. 103–4.
[6] Home Ore Supply Committee Reports, 21.3.17, 14.5.17, 9.7.17.
[7] *Iron and Steel Industry*, 1914–18, p. 105.

IV.—Refractory Materials.

At the outbreak of the war, with one exception, there were ample supplies of refractory materials, and though it had been the custom to import a certain amount of the manufacturers' requirements, all the raw materials, except magnesite, were to be obtained in the country. With the increasing demands for steel, not only were materials needed for the new furnaces, but existing furnaces needed more constant repairs. No serious shortage occurred till 1916, when in order to obtain more satisfactory supplies, a section of the Steel Department was formed (July, 1916), to deal with fire-clay and ganister materials; in the following November magnesite was also controlled and in March, 1917, basic material.

High-class fire-bricks are used in the construction of every kind of furnace, and the whole output of high class fire-bricks was controlled and prices fixed. The capacity of the brick works was 120,000 tons of fire-clay and bricks per month and the actual output in July was 110,000 tons. In spite of loss of labour this output was maintained until April, 1917, manufacturers being encouraged by the Ministry to install labour-saving machinery and to arrange for the dilution of labour. The Ministry was also successful in settling most of the labour troubles which arose. By August, 1917, the average monthly output was 125,000 tons, the equivalent of 50,000,000 bricks, and by April, 1918, the output averaged 135,000 tons.[1]

A more serious shortage occurred in the supply of silica bricks, used for lining acid steel furnaces and converters, glass, copper and other furnaces. The bricks were mostly manufactured in South Yorkshire, Weardale and, to a less degree, in Scotland, the material coming from the ganister quarries in the districts; brick works also existed in South Wales, where there were ample supplies of high grade silica rock.[2] When the Refractory Materials Section was formed the output was 7,966,000 bricks per month, which was quite inadequate to meet the steel makers' requirements.[3] On 25 July, 1916, at a conference on steel production with certain steel makers, the shortage was stated to be serious. A scheme for the extension of acid furnaces was being pressed forward, but there were not enough bricks even for the repair of existing furnaces. The Ministry, in the spring of 1916, had urged brick makers to increase their supplies, but this step was not taken soon enough, so that in July the new steel works which were then being erected were completely held up and complaints to the Ministry had little effect.[4] The first work of the Refractory Materials Section was to allocate the existing output to meet the most urgent needs and to restrict the use of the highest grade bricks. A meeting of manufacturers was held on 8 November, 1916, at the Ministry of Munitions, to consider further means of increasing the supply, with

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[1] *Iron and Steel Industry*, 1914–18, p. 107; C.R. 4368.
[2] *Iron and Steel Industry*, 1914–18, p. 109.
[3] C.R. 4368.
[4] HIST. REC./R./1810/16.

the result that in July, 1917,[1] the output was raised to 10,645,000 bricks per month,[2] and from that time the supply was not only adequate for home needs, but exports were made to the Allies, to Canada, and Australia, and also to Swedish manufacturers working for the Allied Powers.

The control and supply of coke oven bricks, which had before the war been imported from abroad, was also undertaken. The bricks were required to withstand sudden changes of temperature, and to have a minimum of expansion and contraction under varying temperatures. There were few firms in the country with any experience in their manufacture and this delayed the erection of the new coking plants planned in 1916.[3] In September, 1916, the output was 3,370 tons per month, but by June, 1917, output had been increased to 6,376 tons a month, the total for the year being approximately 71,571 tons.[4] The use of bricks was also economised by arranging that high grade bricks should only be used in the more vital part of the ovens and a scheme of priority was devised for all new plants under construction.

Silica sand for lining the actual bath in the acid process was mainly obtained in pre-war days from Belgium and France, but during the war supplies were obtained with satisfactory results from deposits at Leighton Buzzard in Bedfordshire.[5]

Magnesite was the sole refractory material which could not be obtained in Great Britain, and the supply of magnesite bricks, essential in the construction of basic steel furnaces, had, before the war, been obtained almost entirely from Styria. At the outbreak of the war this supply was immediately cut off, and stocks were unfortunately low. A few British manufacturers had made bricks from magnesite imported from Greece, but efforts were at once made to replace the Austrian supplies. The Ministry of Munitions negotiated for the manufacture of bricks with a number of makers, an agreed selling price being fixed, and arranged the provision of tonnage for bringing raw magnesite to Great Britain.[6] Magnesite was imported from Eubœa and India, the Greek material being the most suitable for brickmaking.

At the end of 1916, the political relations of the Allies with Greece made the supply of Eubœan magnesite precarious, while, at that time, only small supplies had been imported from India, and in December a conference was held between the Ministry, the Foreign Office and

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[1] *Iron and Steel Industry*, 1914–18, p. 109.

[2] C.R. 4368.

[3] *Iron and Steel Industry*, 1914–18, p. 108.

[4] C.R. 4368.

[5] *The Mineral Requirements of the British Iron and Steel Industries*, by Prof. W. F. Fearnside (HIST. REC./R./1810/11).

[6] *Iron and Steel Industry*, 1914–18, p. 110.

the Admiralty.[1] The situation was the more serious owing to the increased supplies required with the development of the basic steel programme in 1917, and immediate action had to be taken to relieve the situation. The Ministry of Munitions made contracts for the supply of raw magnesite for the first six months of 1917, with the option of extension for the next six months, with the Anglo-Greek Magnesite Company, Eubœa, the Magnesite Syndicate, Madras, and Allatini Brothers, Salonica, who owned mines at Yerakino. The Anglo-Greek Company was ordered to buy up all the magnesite possible from other mines in Eubœa, and the Admiralty made arrangements for safeguarding the loading of vessels, while the British military authorities were asked to assist in obtaining supplies from Yerakino and Varados. The Indian Government was asked to co-operate in increasing the production of the Salem mines, and arrangements were made for Mr. Merricks to inspect the magnesite deposits at Castiglioncella, in Italy.[2] All imports of magnesite were controlled by the Ministry, and the firm of Messrs. Tennants, Ltd., Liverpool, was appointed to act as distributing and collecting agents for the Government.[3] An order was also issued prohibiting the use of magnesite and magnesite products except for essential purposes, by which a saving of about 1,000 tons a year was effected. With the same object, the drawings for the new basic furnaces were revised and economies in the use of magnesite suggested.[4] As a result of the action of the Ministry, the output of bricks was raised from 256,000 bricks per month in January, 1916, to 510,000 in June, 1917, at which date there were eight or nine months' stocks in hand.[5] The supplies from Eubœa were ensured with the improvement of the Greek situation, and, although a good many cargoes were lost through submarines, sufficient supplies were obtained in 1917 and 1918.

The basic material used for the hearths of basic furnaces is manufactured from calcined dolomite, ground and mixed with a percentage of de-hydrated tar. The dolomite was calcined and quarried by five companies, which, until the end of 1916, were able to meet the requirements of the steel works, their average monthly output being 10,175 tons. With the extension of basic steel making and the adoption of the home ore programme early in 1917, the Iron and Steel Department undertook the control of basic material. In March, Mr. W. J. Jones visited the dolomite firms to make arrangements for extending the calcining plants, with the object of increasing output by 8,000 tons per month, as an output of 18,000 tons per month was needed by basic steel makers for existing furnaces and for the new furnaces which were to be built.[6] By the end of March extensions to

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[1] C.R. 4368.
[2] C.R. 4507.
[3] C.R. 4368; *Iron and Steel Industry*, 1914–18, p. 112.
[4] C.R. 4507.
[5] C.R. 4368.
[6] Home Ore Supply Committee Report, 7.3.17.

calcining plant had been arranged to provide 17,000 tons at an estimated cost of £26,000. These extensions were practically completed by July, 1917, and additional supplies of labour were obtained from South Wales and Cornwall. Hutting accommodation was also provided for 50 men at Oswestry and 25 at Grassington.[1] Owing to delays in furnace construction, the actual monthly requirements of basic material were nearly 8,000 tons less than had been estimated for during the last quarter of 1917. Further schemes for enlarging the basic capacity were adopted in the beginning of 1918, including calcining extensions to give a further output of 4,000 tons a month.[2]

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[1] Home Ore Supply Committee Reports, 2.4.17, and 11.6.17.
[2] *Iron and Steel Industry*, 1914–18, pp. 113–114.

CHAPTER VI.

THE CONTROL OF PRICES.

I.—Introduction.

The history of the control of steel and iron prices by the Ministry is the history of an effort to stabilise the price of steel and iron, at first by voluntary agreement, later by fixing maximum prices under the Defence of the Realm Regulations. The adoption of this policy had economic consequences of the first importance. Any alteration in the price of steel, which, though the raw material of munitions manufacture is the finished product of the iron and steel industries, affected the basis of a thousand munitions contracts, and was reflected along a chain of linked occupations, while conversely, changes in the cost of iron ore, of coal, coke and limestone and of labour were expressed in the cost of the finished product, a further complication being introduced by the prevalence in this industry of sliding scales which regulate wages in accordance with the price of the product.

Control of price is intimately associated with control of supply and of distribution, but as the activities of the Ministry in the two latter directions are dealt with at length elsewhere,[1] it is unnecessary to recapitulate here the steps which had already been taken when the policy of fixing steel prices was decided upon.

The first step, the fixing of a maximum price for shell steel, ultimately involved the control of prices throughout the industry, and an extremely intricate system of rebates and subsidies. It is important, therefore, to be clear on the main point—the reasons which led the Ministry to fix maximum prices. Unfortunately, as the decision was taken in the first weeks of the Ministry's existence, records of the discussions that preceded the decision are wanting, but the main motive is clear enough—it was an attempt to prevent producers from exacting scarcity prices for the necessities of national defence. Shell steel had already risen to £17 a ton, the demand for it was growing daily, and fixing the price at £2 less was a stroke of business upon which the Ministry naturally congratulated itself. At first shell steel only was involved, but it very soon became clear that the price of other classes of steel would have to be fixed in order to prevent makers concentrating on their production at the expense of shell steel. Fixed prices were, therefore, arranged for what was known as "commercial steel," though in the 1915-18 period, the expression is rather misleading, as the government demand for rails, ship-plates and constructional steel absorbed all but a fraction of the output.

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[1] See Vol. VII, Part I.

The price which was settled after negotiation with the chief steel makers, was a price which gave a fair profit on the cost of production, and was a fair incentive to output, but which was lower than the scarcity price that would have resulted from the unrestricted operation of the forces of supply and demand, and lower than the prices ruling in the free market of the United States.

The other motives that led the Ministry to fix prices were obvious enough. In the first place, fixed prices facilitated distribution. The Ministry supplied small firms as well as large according to the urgency of their need and the military value of their products, and in this way introduced an artificial equality of distribution which could be varied as the demand for particular munitions varied. This became specially important when the supply of metals became really short and since the urgency of a buyer's needs could no longer be reflected in the offer of a higher price, the Ministry undertook the work of distributing the available stocks, giving priority to demands which met urgent war needs. This priority system was destined to very great developments, and gradually all materials of which there was a scarcity were rationed, the amount available being distributed among the various War Departments for the production of munitions of war, ships, building, railways and necessary industrial consumption. An elaborate system of priority certificates was set up indicating what, in the opinion of the authorities, was the relative national importance of the work for which the material was required.[1] Thus, machines for shells might for the moment rank lower than machines for making margarine, and steel for shells might rank second to steel for ships. Later on, the same system was applied to the Allied Governments, and in theory at all events, the available resources of the world were distributed in the way that would give them their greatest value in the struggle against the common enemy. The whole of this priority work depended upon the fixing of maximum prices.

A third powerful motive for fixing prices was simplicity in placing and administering munition contracts. A contractor was able to quote lower prices when the price of his raw material was fixed, since he no longer had to cover himself against higher prices in a continually rising market. Further, the Ministry schedules of contract prices were not liable to be vitiated by constant fluctuations, and applications for the revision of the terms of contracts were minimised. Again, as the cost accounting system developed the advantage of being able to reckon the cost of material at a fixed or at all events a seldom varying amount was enormous and very much widened the basis of comparison and therefore the value of these comparative costs.

But the Ministry soon had to realise that fixed prices meant falling production at a moment when every ton of steel was urgently wanted. The prices fixed in the early days of the Ministry gave the manufacturer a fair and indeed in most cases a generous return for his outlay, but with rising costs of labour, freight, heat, light and power,

[1] For an account of the Priority System, *see* Vol. VII, Part I.

the return became insufficient to stimulate him to produce at his utmost capacity or to undertake great extensions of plant. Since increased production was a vital necessity for the Ministry, a larger return had to be allowed to the steel maker, and as will be seen below, the problem was approached in different ways according to the class of steel dealt with. In some cases the maximum prices were raised in order to reflect rising costs of production, in other cases production was first stimulated by very generous capital advances and then by granting subsidies.

It soon appeared that fixing the price of steel involved fixing the price of all its constituents, and this could not be done until the rise in the freights of foreign ore was checked. Since the Government could not control the freights demanded by neutral ships (who carried 40 per cent. of the foreign ore to England), the only way of preventing a further increase in the price of foreign ore, and a consequent increase in the price of home ore, was for the Government to pay all freights above a certain level.[1] This system of freight rebates was in itself an indirect subsidy to the iron and steel trade. The next step was to fix the price of coke, which was a governing factor in the cost of iron and steel production. Freights and coke prices being fixed, it became possible to fix the maximum prices for pig iron.

By July, 1916, therefore, maximum prices had been fixed under the Defence of the Realm Regulations for shell steel, commercial steel, coke and pig iron. It was hoped that this would not only keep prices stable in the thousands of munitions contracts, but would also put a stop to the steady rise of wages under the sliding scales, the men employed in this trade having already secured advances far in excess of those obtained in the other munitions trades.

For a short time maximum prices had the effect that had been hoped for and prices and wages remained level, but this state of equilibrium did not last long, and in the autumn of 1916 the various groups of iron masters were agitating for an increase of price on the ground that their costs of production were increasing. The Ministry had to choose between sanctioning an increase of maximum prices or keeping these prices level by granting rebates and subsidies. The former alternative was chosen with regard to non-hematite pig iron, and increases in prices varying in different districts were sanctioned, but for reasons that will be discussed in detail later[2] the Ministry decided to keep the price of hematite pig iron level by adopting the policy of granting rebates or subsidies, and from that time forward maximum prices became more amd more artificial, disguising instead of reflecting the real cost of production. Moreover, when the unrestricted submarine campaign forced the Government to bear the cost of war risk insurance above two guineas per cent. (January, 1917), another indirect subsidy was given to the trade. The Coal Controller's award of 1 September, 1917, was another disturbing factor, which meant greatly increased costs of production throughout the iron

[1] See below, pp. 105-107.

[2] See below, p. 98.

and steel industry, and in order to prevent a big rise in prices a further subsidy was given to makers of hematite pig iron, and the subsidy policy was extended for the first time to makers of other classes of pig iron. The subsidies were necessarily increased by the war bonuses of 12½ per cent. to time workers and 7½ per cent. to piece workers, and by the Coal Controller's second and third awards on 24 June and 8 July, 1918.

In the meantime the Ministry had been advancing money on a very large scale for steel works and blast furnace extensions, and in so far as the terms allowed were better than those upon which capital could have been obtained in the open market, was thereby subsidising the industry, while the fact that it had been forced to take over the hematite iron ore mines, working them at a loss, amounted to another concealed subsidy. In addition the Ministry was importing basic pig iron from America and selling it to British steelmakers at a loss, had undertaken a certain financial responsibility for the production of iron ore briquettes from Sydvaranger, and was allowing coal to be carried to Spain at much below the normal freight in order to keep the mineral railways going. These two latter undertakings were, from the financial point of view, of comparatively small importance, but they illustrate the ramifications of the subsidy and rebate system, and the difficulty of estimating the full charge borne by the Government.

It should be noticed, however, that this elaborate machinery effected its main object—that of keeping steel prices level. It was not until November, 1917, that subsidies were granted to meet the increased cost of manufacturing steel, and even then the subsidy given on the production of commercial steel was diminished by a refund of part of the price of shell steel.

But the danger of allowing the whole industry to rest upon an artificial basis was not ignored. Owing to the complexities of the system and to the variations in different districts only experts could tell what was the total subsidy given by the State to the trade, or how much it really cost to produce each ton of steel and iron sold at the maximum prices, and there was evidence that the iron and steel trade itself was ignorant of the full extent to which it was being subsidised. The decision that the Allies ought to be charged real instead of nominal prices for the steel and iron exported to them led to the preparation of estimates of the difference between cost of production and maximum prices. In April, 1918, it was estimated that the cost of rebates and subsidies, excluding freight and war risk insurance, amounted to about £12,000,000 per annum, and excess freight and insurance charges to £23,000,000 per annum.[1]

This was followed up, in July, 1918, by a report by Mr. Guedalla,[2] which analysed the whole system of rebates and subsidies, estimated

[1] D.F.3/P.A.C./13.

[2] Report to Council Committee on Demobilization, 29 July, 1918 (HIST. REC./R./661/22).

its cost to the Government and its effect upon the trade, and recommended the appointment of a committee to consider the possibility of removing subsidies by gradual steps, and restoring the trade to a natural instead of an artificial basis. The arrangements for fixing steel prices, which originated in a well-intentioned effort at economy, and which had saved, perhaps, three or four million pounds per annum in the placing of munition contracts, had resulted in an extremely complicated and artificial system, and it appeared that if the subsidy system was pursued the independence of the whole iron and steel trade might be affected. The abandonment of subsidies would be a delicate operation, and the trade would require long notice for the adjustment of stocks, etc. He thought it would be best to remove subsidies, and adjust maximum prices by instalments so as not to create too great a convulsion. These arguments were supported by the Board of Trade, which condemned the system as most pernicious. The maintenance of a fictitious price made it practically impossible to estimate conditions in the future ; manufacturers could not make for stock and could not quote for after-the-war requirements. A special committee under Sir Clarendon Hyde was appointed to consider Mr. Guedalla's suggestions, which were adopted, and on 13 November the Committee recommended the withdrawal of subsidies in two stages.[1]

It is hoped that the foregoing paragraphs will have indicated the guiding threads of the tangled story that follows.

II.—Steel.

(*a*) Control of Shell Steel Prices by Agreement.

In June, 1915, the price of shell steel was £17 a ton. After negotiation with the Steel Makers' Committee, which had been formed on 14 June, 1915, agreements were drawn up fixing shell steel prices, for the remainder of 1915, at £15 per ton up to and including 6-in. shell, with higher prices for larger sizes.[2] Under these agreements the shell steel makers were not bound to replace any steel found to be defective after leaving their works unless it exceeded 10 per cent. of the total, a concession which, incorrect in principle and unsatisfactory in practice, was introduced in order to encourage inexperienced firms to take up the manufacture of shell steel. On 10 October, 1915, the operation of these prices was extended to 1916.[3]

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[1] See below, p. 132.

[2] 29 June, 1915 ; 19 July, 1915. From C.R. 1670 it appears that the scheme for fixing prices was suggested by the Director-General of Munitions Supply on 1 July, 1915, and approved 7 July, 1915.

[3] Sir L. Llewelyn's Papers, 20.

(*b*) CONTROL OF COMMERCIAL STEEL.[1]

The fixing of shell steel prices made commercial steel more profitable and threatened to diminish the output of the former. It was necessary therefore, to fix the price of commercial steel in order to equalise matters.

The following table shows the rise in prices since the beginning of the war :—

	Prices. June, 1914.			*Prices. December, 1915.*		
	£	*s.*	*d.*	£	*s.*	*d.*
Rails	6	5	0	11	0	0
Ship Plates	6	0	0	11	17	6
Boiler Plates ..	7	0	0	—		
Angles	6	10	0	12	0	0
Joists and Girders ..	6	15	0	11	2	6

At a meeting on 6 January, 1916, the chief difficulties in fixing a maximum price for commercial steel products were discussed,[2] the rise in freights, which had increased by 3*s.* a ton during December, and the varying price of hematite pig iron. The steel makers were anxious for a sliding scale of prices, varying with the price of pig iron, but the Ministry stated that a definite price must be fixed for a certain period, with the possibility of a revision at the end of the time. Finally the steel makers agreed to accept the following maximum prices on the basis of hematite at £6 2*s.* 6*d.* per ton :—[3]

	£	*s.*	*d.*
Rails (over 60 lb. per yard)	10	17	6
Ship Plates	11	10	0
Boiler Plates	12	10	0
Joists	11	2	6
Angles	11	2	6

In March, 1916, the Ministry made an unsuccessful effort to get the prices of shell steel reduced by £2 a ton, owing to the assumption by the Government of responsibility for freights[4] and the fact that negotiations were in progress for fixing the price of hematite pig iron at £6 2*s.* 6*d.* At conferences held on 29 and 31 March the steel makers resisted the proposal to reduce shell steel prices, and in view of the shortage of steel the Ministry decided to continue the price of £15 a ton for another three months, while enquiries were being made into the cost of production.[5]

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[1] Rails, plates, angles, etc.

[2] Sir L. Llewelyn's Papers, 158A.

[3] Only the chief classes of commercial steel have been dealt with in this outline. The controlled price of other items was proportionate.

[4] *See* below, pp. 105-108.

[5] 94/S./3131. (Printed) *Weekly Report*, No. 37, III (8th April, 1916).

(*c*) CONTROL OF STEEL PRICES UNDER REGULATION 30 (A).

As the demand for steel and iron increased and the cost of production rose, the arrangement for fixing prices by voluntary agreement began to break down. Certain steelmakers had never come into the arrangement for a fixed price, and evasion of the maximum prices became frequent.[1] On 26 June, 1916, therefore, Mr. Llewelyn suggested that the principal classes of coke, iron and steel should be placed under Regulation 30 (A) of the Defence of the Realm Regulations, thus forbidding dealings in these materials except by permit from the Admiralty, Army Council or Ministry of Munitions. He proposed that a general permit should be issued by the Ministry sanctioning dealings at prices not exceeding maximum prices to be laid down by the Ministry. Precedents for such action might be found in the War Office announcements of 23 May, 1916, with regard to Russian flax and tow, and of 16 and 21 June with regard to raw sheepskins and wool. Moreover, the principle of fixing maximum prices by means of Regulation 30 (A) was already in general use in the aluminium trade, where it was working with good results,[2] and had been recognised as legitimate by the Defence of the Realm (Losses) Commission, which had heard and determined a number of claims based on the fixing of prices by means of Regulation 30 (A).

Sir Frederick Black agreed with this proposal, which was discussed and approved by Mr. Lever and Mr. Chetham Strode (27 June, 1916).[3]

The Admiralty, War Office and Board of Trade were asked whether they had any objections to the issue of the proposed order (30 June), and replied in the negative, the Admiralty and Board of Trade criticising two minor points only in the proposed schedule.[4] A circular was prepared for issue to the trades, explaining the object of the order, and that it was not to apply to contracts in writing entered into before a specified date,[5] or to small transactions involving not more than five tons, which exempted "the local ironmonger and the village blacksmith."

The order was signed by Mr. Lloyd George on 7 July and issued on the same day.

Except by special permit from the Ministry, the maximum prices laid down in the schedule annexed to the order might only be exceeded in the case of—

(*a*) sales of quantities below five tons.
(*b*) finished steel rolled from steel bought by the seller.
(*c*) material sanctioned for export.

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[1] 94/S./2401 ; A.M. 2/536.
[2] On 7 December, 1915, an order had been issued under Regulation 30 (A) forbidding dealings in all kinds of aluminium or alumina without a permit.
[3] A.M. 2/536.
[4] *Ibid.*
[5] The circular was issued on 10 July (A.M. 2/536).

The schedule confirmed the existing maximum prices of both shell steel and commercial steel, certain "extras" for special sizes and qualities being allowed.

On 7 September, 1916, the steel makers obtained the consent of the Ministry to the adoption of the scale of extras as laid down on the Scotch list, which were higher than those current in the first quarter of 1916. A further scale of extras for small sizes was subsequently reduced on the representations of the Admiralty. The Admiralty only agreed to the scale for the period of the war, and on the understanding that an official list of the approved extras be printed and circulated throughout the trade as the only legal charges.

(*d*) Attempt to Reduce Maximum Prices of Shell Steel.

From July to September, 1917, the Ministry was engaged in another attempt to reduce the price of shell steel. A reduction of £2 per ton was proposed by the Finance Department. After lengthy negotiations the steel makers agreed to accept a reduction of 30*s*. per ton on English shell steel from 1 October onwards, provided the price for export was not changed. In return the Ministry was to contribute a subsidy of 10*s*. per ton on steel plates, sections, girders and rails delivered from 1 October onwards, and sold on the basis of £11 10*s*. for plates, £11 2*s*. 6*d*. for sections and £10 17*s*. 6*d*. for rails. Commercial steel at existing prices was unremunerative, and in cases where a reasonable profit could not be obtained, even with the help of the subsidy, the Ministry was, after investigation, to raise the subsidy if necessary.[1]

A draft letter to the Treasury defended the suggested subsidy as follows:—[2]

> "There are objections to altering the standard prices, as these form the basis of numerous contracts as well as wages rates. The Minister therefore proposes that the standard prices be left unchanged, but that a direct subsidy of 10*s*. per ton on plates, sections and rails should be paid by the Ministry on all such steel. It is recognised that the proposed subsidy may extend to a certain amount of steel which is not used directly for Government work, but any such tonnage represents a very small proportion of the whole, and it would be practically impossible to determine the exact amounts unless by an exhaustive following up of every ton manufactured to its ultimate use. Mr. Churchill desires to add that it is possible that labour questions may be raised by this course, as the selling prices of plates, sections and rails form the basis of the sliding scale of wages, but for the reasons given the Minister considers it desirable to make this payment by way of a direct subsidy rather than an addition to the prices, and this still leaves it open for the steel makers to include the subsidy in their average prices for wages determination if the accountants so decide."

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[1] 18 August, 1917 (D.S.P./Gen./54).
[2] Draft dated 7 September (D.S.P./Gen./54).

A month later the whole situation was changed owing to an increase of 1*s.* 6*d.*, a ton in the wages of coal miners, which would increase the cost of steel production by about £1 per ton.[1]

The question whether the increased cost of production was to be met by increasing the maximum prices or by a government subsidy was considered by the Ministry.

The arguments in favour of subsidies were as follows:—

(1) Claims by contractors for increase in current contract prices would be avoided.

(2) Contracts upon a cost plus percentage basis would give higher profits to contractors if the maximum prices were increased. The new Ministry contracts of this class contained a clause preventing the contractor making a profit out of increased cost, but the contracts placed by the Admiralty for ship construction contained no such safeguard,.

(3) An increased price of pig iron and steel would raise the price of manufactured articles by more than the amount of the increase as the contractor would inevitably charge a higher rate of profit, and claims that costs had increased would be set in motion everywhere. The actual increase in cost of production would vary in different districts and the price fixed would have to be sufficient to cover the maximum increase. Different subsidies might, however, well be granted in different districts.

(4) Royalties for certain iron ore mines were dependent on the price of pig iron and would be further increased. There were, however, comparatively few of these cases.

(5) A subsidy was favoured by the Scotch steel makers because it would enable them to buy materials economically and sell their product at the old price, whereas a direct advance in prices would make it difficult to buy materials at the old figure.

(6) The actual increase in cost of production owing to the rise in the price of coal would vary in different districts.

On the other hand, there were many arguments for increasing maximum prices instead of granting subsidies.

(1) The existing price of iron and steel was maintained at an artificially low level to all consumers. As long as Government Departments were directly or indirectly the only consumers this was not a serious objection, but the Allies ought to bear their share of the increased production cost of the materials supplied to them. It would be impossible to recover such portion of the total subsidies as applied to pig iron absorbed by private consumers at home and abroad, but the loss under this head would be very small as only about 2 per cent. of the steel, and from 4 to 10 per cent. of the pig iron produced was used for other than government purposes.

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[1] P.M./Gen./1124; D.S.P./Gen./54.

(2) An increase in price might retard the consumption for other than government purposes, but, for the reasons given above, this economy would only affect a very small percentage of the steel produced.

(3) The North East Coast steel makers urged that any extension of the system of subsidies would involve difficult enquiries into costs of management.

(4) Labour as a whole might complain that the operation of sliding scales for wages was upset by the granting of subsidies.

The practice in this matter varied in different districts. In Scotland the steelmakers regarded a subsidy as an advance in price and communicated the amount of it to their workmen, whose wages then rose on the sliding scale. In other districts, the North East Coast and West Coast, labour had made serious complaints that the employers had not communicated the nature of the subsidy arrangements, or allowed wages to be affected thereby.

In order to avoid complaints of this kind the Labour Department advised that if the increased cost of production was met by the grant of a subsidy, the Blast Furnacemen's & Steel Smelters' Unions should have the matter fully explained to them, with particular emphasis on the point that the subsidy did not carry any increased profit to the employers. This might prevent any demand for an increase of wages. On the other hand, the arrangement by which a subsidy was to be given on the production of commercial steel would increase the profits of employers and the labour situation would have to be dealt with carefully.[1] The Steel Department was strongly in favour of a subsidy rather than an advance in price, supporting its view by the following arguments :—

(1) The advance in price of 2*s*. 6*d*. per ton of coal was estimated to contain a profit to the State of about 1*s*. 8*d*. per ton—the cost of the rise in wages being estimated at 10*d*. per ton.

(2) Steel sheets were used for tin plate required for importation of food, not only for the Army and Navy, but for general use, and an increase of price might conceivably necessitate a subsidy by the State to maintain at a low level certain food prices just as the cost of the loaf was maintained at an artificially low level by a subsidy.

(3) Even where a proportion of the capital expenditure upon steel work in building construction was paid by the Ministry such proportion should, strictly speaking, in justice to the contractors, be increased in order to meet the increased cost of construction not foreseen when the scheme was undertaken. In other words, the

[1] 8 November, 1917 (P.M./Gen./1124).

State should bear the extra and unforeseen cost of steel required for such extensions and could not fairly charge the contractor even with his proportion of the increased cost.

(4) If the price of steel was raised the extra cost of steel for maintenance and repairs would diminish assessable profits and would indirectly be paid by the Government out of the excess profits duty.

After weighing the arguments on both sides the Ministry decided to grant a subsidy in lieu of making a change in basis prices, and after further negotiation with the steelmakers an agreement, which was to apply to the months of November and December, was arrived at (28 November), and confirmed by the Treasury on 5 December.[1]

The arrangement in its final form was as follows :—

(1) The existing basis prices of shell steel for Britain and Allies were to remain unaltered, but in the case of shell steel for Britain were to be subject to a refund by each maker direct to the Government of 25*s*. per ton, and the margin allowed to the steel maker for defective material was to be reduced to 5 per cent. calculated on the deliveries during the above period to each buyer, the sub-contractors under each Board of Management to be regarded for this purpose as one buyer.

(2) The existing basis prices of plates, angles and other steel to which letters A to L applied were to remain unaltered, but in the following items were to be supplemented by subsidies paid directly by the Ministry to each steel maker at the following rates per ton, viz. :—

	s.
Ship, bridge and tank plates (and extras per List A)	20
Boiler plates (and extras per list C)	20
Chequer plates (and extras per list T)	20
Angles (and extras per list D)	15
Joists (and extras per list H)	15
Rails (50 lb. per yard and over)	15

No other alterations were to be made on the existing prices of the other items and their respective extras per lists B, E, F, G, K, and L.

(3) The Ministry would be prepared to give special consideration to any cases in which it was satisfied that these prices and subsidies had resulted in hardship to the steel makers.

(4) These changes were to take effect upon all deliveries from makers' works from 1 November, 1917, until 31 December, 1917.

(5) The existing maximum prices of hematite iron and other pig iron were to be maintained at the existing figures with the exception of an increase of 5*s*. per ton on Lincolnshire pig iron, and 2*s*. 6*d*. per ton on Cleveland iron used for steel making.

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[1] D.S.P./Gen./54 ; P.M./Gen./1124.

The cost of the revised arrangement was estimated as follows :—

	£
Subsidy on pig iron per annum ..	5,000,000
Subsidy on merchant steel (about 15*s.* per ton)	5,000,000
	10,000,000
Reduction of 25*s.* per ton on shell steel..	3,000,000
Net subsidy	7,000,000[1]

It will be seen that by this agreement the Ministry, after considering the arguments for and against artificial prices, had accepted the principle of giving a subsidy instead of allowing an increase of maximum prices, the chief argument being that the standard prices formed the basis of a great volume of munitions contracts as well as of wages rates, and that the amount of steel which was not used for government purposes was negligible. The fact that the selling prices of plates, sections and rails formed the basis of sliding scales of wages was recognised, but it was suggested that there should be no attempt to conceal from the trade unions the granting of a subsidy. The inclusion or exclusion of the subsidy in the price which fixed the wages scales should be left to negotiation.

A substantial increase in these subsidies was granted early in 1918 in order to meet the increased cost of production, due to the wages awards of 12½ per cent. and 7½ per cent. After conferences with representatives of the Steel Makers' Associations the Ministry agreed, on 28 February, 1918,[2] that the subsidy on plates should be increased to 30*s.* a ton, and on angles and joists to 17*s.* 6*d.* a ton from 1 January, 1918 to 30 June, 1918. Eight months later (1 October) another ten shillings was added to the subsidy on plates, making 40*s.* in all ; including the cost of a refund on the increased price of coal and coke and increased wages it was estimated that, at the date of the Armistice, the subsidy on plates amounted to £2 10*s.* per ton.

(*e*) Rebate on Basic Iron from United States of America.

In order to increase steel production by utilising American supplies of pig iron, which stood at a considerably higher price than the controlled price of British pig iron, the Ministry adopted the policy of supplying this iron to steel makers at the prices ruling for British pig iron. During the eighteen months from 1 January, 1917, to 30 June, 1918, about 150,000 tons of basic pig iron were bought by the Ministry in the United States and sold to steel makers in the United Kingdom

[1] P.M./Gen./1124.

[2] Memorandum of agreement between the Ministry and the Steelmakers' Association (Hist. Rec./R./661/17).

at the controlled prices. This, of course, involved a considerable loss to the Government, but as the freight paid could not be ascertained, the actual amount of loss could not be definitely stated. A further 180,000 tons was to be imported from July, 1918 to December, 1918. The iron cost $33 (about £6 17*s*. 6*d*.) per ton exclusive of freight, as compared with an average price of £5 per ton for English basic pig iron. The government freight rate amounted to £4 2*s*. 6*d*. per ton. The cost of this re-sale at controlled prices was estimated at over £1,000,000,[1] viz. :—

	£
Freight on 180,000 tons at £4 2*s*. 6*d*. ..	745,000
Excess price 180,000 tons at £1 17*s*. 6*d*.	337,500
	1,082,500

(*f*) CONTROL OF HIGH SPEED STEEL PRICES.

As has been seen above, when the Ministry was formed, supplies of tungsten for the production of high speed tool steel were very difficult to obtain ; in fact, wolfram was not smelted in the United Kingdom before the war, though a limited quantity was dealt with in France. About 60 per cent. of the world's production of wolfram, however, came from the British Empire, and in November, 1915, an arrangement was made with the British colonies and dependencies by which the whole of the wolfram ore was taken over by the British Government at 55*s*. per unit, smelting works for the production of tungsten being established at Widnes. The official selling price of wolfram was 60*s*. per unit, and on this basis the price of ferro-tungsten was fixed at 5*s*. 6*d*. per lb., and the price of tungsten powder at 6*s*. 3*d*. a pound.

By these means practically all the tungsten required for making high speed tool steel for Great Britain and the Allies was obtained, and in addition a substantial sum of money was saved. The price of tungsten in America had risen to over 20*s*. per pound in 1917, and by April, 1917, it was calculated that approximately £1,750,000 had been saved on the tungsten used in munition making.[2]

The fixing of the price of tungsten enabled the Ministry to fix the price of high speed tool steel, for which exorbitant prices were being asked in the autumn of 1915. The Raw Materials Department called conferences of the Tool Steel Association on 8 December and 29 December, 1915.[3] The makers claimed that the price was reasonable owing to the fact that the price of tungsten had risen by 50 per cent, and that coke had risen in price. Further, selling costs were governed by the high production costs of small firms who produced good tool steel, but who would return to the manufacture of ordinary steel if the selling price of tool steel was reduced, and by the high prices

[1] HIST. REC./R./661/22.
[2] HIST. REC./R./400/42.
[3] Sir L. Llewelyn's Papers, 158.

obtainable in America. Mr. Llewelyn's suggestion that the export of high speed tool steel might be prohibited was strongly condemned by the makers. They thought 3*s*. and 4*s*. a pound a fair maximum price, but finally agreed to a price of 2*s*. 10*d*. and 3*s*. 10*d*. per pound (1 January, 1916). This price was to apply also to high speed tool steel for the Allies, the price of exported steel remaining for the moment unregulated. The increased shortage, however, made it necessary to conserve supplies, and in May, 1916, the export of high speed steel was prohibited.[1] The maximum price remained unchanged until 15 February, 1918, when it was raised to 3*s*. 8*d*. and 4*s*. 5*d*. a pound.

(*g*) CONTROL OF STEEL SCRAP PRICES.[2]

The war, of course, enhanced the value of steel scrap, but in spite of a rapid rise of price it remained uncontrolled until July, 1916. The chief sources of supply of steel scrap were the various munition factories, and importation from Holland, and it was readily bought both by the steel makers, the bar iron makers and the tin plate makers. The highest price reached before the war (in 1913) was 67*s*. 2*d*. per ton. By the end of 1915 it had risen to about £5 a ton, and the tool steel makers and bar iron makers were complaining. In January, 1916, therefore, they proposed that the Ministry of Munitions should sell to each maker a quantity of scrap (not more than 10 per cent. of the steel supplied) at 90*s*. a ton, and 40*s*. for turnings and borings. The Ministry offered to sell at 95*s*. and 45*s*. including delivery at the steel makers' works, each steel maker to have a definite claim upon a quantity of scrap proportionate to his output of shell steel. On 8 February, the steel makers stated that they were willing to accept this, but in view of the increasing demand for steel scrap, the high prices ruling in America, and the necessity of keeping prices high in order to attract steel scrap from the Continent which might otherwise find its way to Germany, the Ministry allowed the matter to stand over until re-opened by the steel makers themselves. Prices continued to rise rapidly, and by May the South Staffordshire iron masters were complaining of the scarcity of scrap, even at £6 15*s*. or £7 a ton.

In the negotiations for fixing a maximum price that followed, one of the chief difficulties was the variation in the cost of carriage. In Scotland, steel scrap could be obtained close to the works where it was to be used, but in South Wales, which produced no steel scrap but consumed a great deal, the buyer had to pay 13*s*. to 15*s*. a ton for carriage. It was also difficult to fix a fair price for turnings, owing to variation in quality.

The prices fixed on 7 July, under Defence of Realm Regulation 30 A, were £5 10*s*., for heavy steel melting scrap, and £2 15*s*. for turnings and borings, both delivered free at the makers' works.

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[1] HIST. REC./R./1810/42.
[2] HIST. REC./R./661/2, 680/1.

A new order, 1 November, 1916, divided scrap into four classes :—

(1) Heavy melting scrap, the price of which remained unchanged at £5 10*s*.
(2) Special heavy scrap suitable for crucible use at £5 15*s*. per ton.
(3) Turnings and borings, the price of which remained at £2 15*s*.
(4) Special short extra heavy borings at £3 15*s*.

All were for steel delivered at buyers' works.

Prices were again fixed by Order on 1 January, 1917, when crucible scrap was omitted. Under this new schedule prices were reduced to £5 5*s*. for heavy scrap, £2 10*s*. and £3 10*s*. for turnings and borings and special short heavy extra borings respectively. But, on the other hand, the carriage at actual cost or at a fair average rate agreed between the seller and buyer might be charged to the buyer up to a maximum of 10*s*. per ton.

Hitherto prices had only been fixed for steel scrap sold without guaranteed analysis, but on 28 August, 1917, under an amended Order, the price of heavy steel scrap sold with a guaranteed analysis was fixed at £6 5*s*. per ton for scrap containing not over ·04 per cent. phosphorus and sulphur, and £6 for scrap containing ·05 per cent.

The accompanying table shows the maximum scale of prices as fixed at various times :—

Steel Scrap Sold without Guaranteed Analysis.

	Heavy Steel Melting Scrap.	Special Heavy Scrap for Crucible use.	Turnings and Borings.	Special Short Extra Heavy Borings.
7 July, 1916 ..	£5 10*s*. delivered buyers' works.		£2 15*s*. delivered buyers' works.	
1 November, 1916	£5 10*s*. delivered buyers' works.	£5 15*s*. delivered buyers' works.	£2 15*s*. delivered buyers' works.	£3 15*s*. delivered buyers' works.
1 January, 1917 ..	£5 5*s*. plus carriage up to a maximum of 10*s*. per ton.		£2 10*s*. plus carriage up to a maximum of 10*s*. per ton.	£3 10*s*. plus carriage up to a maximum of 10*s*.

Steel Scrap Sold with Guaranteed Analysis.

28 *August*, 1917.	£	*s*.	*d*.	
Heavy steel scrap containing not over ·04 per cent. phosphorus and sulphur	6	5	0	per ton.
Heavy steel scrap containing not over ·05 per cent...	6	0	0	per ton.

II. Iron Ore.[1]

(*a*) CONTROL OF FREIGHT.

As has been seen, the adoption of the policy of controlling steel prices necessitated sooner or later the control of its constituents. It was recognized from the beginning that the control of iron ore was of primary importance, and that the root difficulty of the question was that of freight. For even were the prices of ore from British mines

[1] Sir L. Llewelyn's Papers, 158.

controlled, only two-thirds, roughly speaking, of the ore needed would be affected,[1] and very high freights were being paid for the iron ore imported from Spain, North Africa and the Mediterranean.

During 1913, the United Kingdom imported 4,800,000 tons of ore from Spain, the price of the best Bilbao Rubio averaging about 25*s.* per ton delivered in the United Kingdom. This included freight at 8*s.* 6*d.* per ton, and the net price received by the Spanish merchant was 16*s.* 6*d.* per ton or 22·3 pesetas (at 27 pesetas to the £ sterling). By the beginning of 1915, freights had risen to 24*s.* 6*d.* from the Mediterranean and 26*s.* 6*d.* from the Bay of Biscay, and owing to the rise in freights iron masters were declining to abide by the scale prices for pig iron already arranged by agreement with the Ministry. Some furnaces were already out of blast and production was falling off. The disturbance had spread to the steel makers, and there was a prospect of innumerable contracts for shell and other munitions being thrown into chaos. Shipbuilders were being asked to pay higher prices for steel for the mercantile work arranged with the Admiralty and constructional engineers were quoting higher prices for aerodrome sheds. On the other hand, if Spanish ore freights were to be standardised, the existing scale of iron and steel prices would be adhered to, and there was a possibility that steel prices might actually be reduced, as the element of speculation would be almost eliminated.

Mr. Llewelyn therefore suggested (11 February, 1916) that the Government should become responsible for freights, that a Government broker should be appointed to charter all the tonnage available for bringing ore into the country, allocate the tonnage chartered among ore importers at a fixed standard rate, thereby eliminating competition for tonnage, while it would be possible to divert ships from congested ports. This proposal was approved by Mr. Lever, and referred to the Treasury (3 March).[2]

About 90 per cent. of the ore was carried in neutral vessels and high freights had to be paid to attract them. It was calculated that the tonnage involved would be about 3,000,000 tons per half year. A freight advance of 3*s.* per ton over existing rates would cost £450,000 for the six months, and an advance of 5*s.* per ton would cost £750,000. These figures would of course be increased if tonnage grew scarcer, or reduced if British boats were requisitioned for the trade by the Admiralty and paid at lower rates. Existing charters which were mainly at or below standard rates would not be interfered with, and to this extent there would be a further reduction in the liability of the Government. There was also reason to believe that by stopping the scramble among ore importers for the limited tonnage the Ministry's broker would be able to charter ships at rates lower than those then ruling. The primary duty of the broker would be to secure tonnage without reducing freights to a point which might divert neutral vessels to other traffic.

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[1] In 1913 the output of home ore was 15,997,328 tons and of imported ore 7,442,244 tons. In 1917 the figures were 15,027,902 and 6,189,655.

[2] A.M.2/265

The Ministry argued that the increased cost of freight must be borne by the country if the ore was to be imported at all, and as nearly all the steel production was required for government purposes (including railways), the Government would in any case have to bear the excess freights. It was better to meet the cost at the starting-point and not to allow it to be transmitted from stage to stage, each manufacturer adding a protective margin.

Again, the price at which Spanish ore could be mined and shipped to England determined the price at which British ore—approximately 15,000,000 tons per annum—was sold, as the one competed with the other, and the rise in freights had inflated the price of British ore. Mr. Lever also emphasised the fact that the wages of iron ore miners were regulated by the price of pig iron, and that therefore a rise in freights meant a rise in miners' wages. Similarly landlords' royalties on iron ore, owing to the high price of pig iron, were at least double pre-war rates.

This scheme was approved by the Admiralty,[1] and preliminary Treasury sanction was obtained on 7 March, 1916,[2] this sanction being confirmed on 18 May, 1916.[3] It applied to iron masters in all districts, and circulars explaining the working of the scheme were issued on 22 March.[4]

The freight basis as arranged under this scheme was fixed at 17*s.* per ton from Bilbao to all ports of discharge, the Government becoming responsible for all freight in excess of this and for demurrage arising from congestion. The iron masters were to pay the full freight and claim the difference from the Ministry, producing certificates that the iron delivered at the maximum prices represented all the ore received.[5]

The freight rebate applied only to the ports named in the schedules issued by the government broker, and was not extended to the Scandinavian ports. It was only allowed on ore used for the production of pig iron or steel sold under the maximum price scheme, and would not be allowed on ore used to make pig iron for export "except to Allies who share in the rebate scheme."[6]

An interesting report on the working of the scheme was made to the Treasury on 23 June, when it had been in force for several months.[7] Mr. Lever stated that between 23 March and 25 May, 318 steamers had been chartered of a total tonnage of 1,085,600 tons, 125 being British ships and 193 neutral ships. Assuming that all

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[1] The Admiralty criticised and amended the proposed form of charter party 24, 29 March (A.M.2/343).

[2] Conference on 7 March (A.M.2/265).

[3] 10223/16 in A.M.2/265; C.R.V./S./6.

[4] A.M.2/265.

[5] This was an attempt to prevent iron masters claiming this ore rebate for iron sold abroad at prices above the home maximum.

[6] 16 May, 1916 (A.M.2/265); C.R.V./S./197.

[7] A.M.2/265.

the ore imported was used for the production of pig iron sold at the maximum price, the expense incurred by the Government in meeting the excess above parity rates was £167,000, and the amount to be received by the Government on steamers chartered below parity rates was £13,000. A considerable percentage of the ore would be used for purposes which did not come under the maximum price arrangements and would therefore not involve the Government in any expense for freight rebates. The operation of the scheme had effected a considerable reduction in freights which on 30 March were 26*s*. 6*d*., from the Bay of Biscay and 24*s*. 6*d*., from the Mediterranean to the East Coast ports, but had fallen to 19*s*. 6*d*., and 18*s*. 6*d*., by 25 May. A few claims for demurrage were under investigation, but except in the case of one steamer, detained at Newport owing to labour troubles which might possibly involve £1,000 to £1,200, very little expense had so far been incurred by the Government accepting responsibility for demurrage, owing to the fact that experienced shipping agents had been appointed to represent the Government in all the principal ore discharging ports.[1]

(*b*) EXTENSIONS OF FREIGHT REBATES.

In May, 1917, the Ministry asked the Treasury to sanction the payment of freight rebates on all iron ore imported from Spain and the Mediterranean without restriction as to its use. This involved the inclusion of the following, which were excluded under existing arrangements :—

(*a*) Ore used in steel making. This affected a small amount of ore only.

(*b*) Ore used for hematite pig iron which was not sold at controlled prices, *i.e.*, chiefly exported hematite pig iron, of which about 300,000 tons per annum went to the Allies.

(*c*) Ore used for making hematite pig iron which was converted at the same works into steel, the latter being sold at uncontrolled prices. About nine firms made both pig iron and steel and the total quantity delivered by them at uncontrolled prices was 45,000 tons during the first quarter of the year, which was less than 2 per cent. of the steel output of the country.

(*d*) Ore used for making basic pig iron. Very small quantities of Spanish and Mediterranean ores were used for basic iron, but as the basic iron was all sold at controlled prices, the makers were undoubtedly entitled to the rebate.

(*e*) Ore used for making spiegel-eisen—a few thousand tons a month. The price of spiegel-eisen was so far uncontrolled, but no difficulty was anticipated in fixing its price.

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[1] See Vol. VII, Part V.

In putting the case for an extension of the system of freight rebates before the Treasury (18 May, 1917),[1] the Ministry stated that until recently the excess freight charges covered by these rebates had been small. Some British ships were still being chartered at parity rates or even lower, the general average being 26s. per ton. In the case of neutral tonnage, however, freights were very high, as much as 75s., having been paid as against the parity rate of 17s.

As the allotment of tonnage remained with the Shipping Controller, importers who, under the existing scheme, could claim no freight rebate, might be compelled to refuse to accept neutral ships consigned to them at these exorbitant freights. A further anomaly arose from the fact that the steel makers who bought pig iron at maximum prices obtained the advantage of the rebate allowed on the iron ore, irrespective of whether their steel was sold at controlled or uncontrolled prices, while the nine steel firms who made and used their own pig iron were placed at a disadvantage in respect of any steel sold by them at uncontrolled prices. They were driven to sell their own pig iron at the maximum price (in order to secure the rebate), and then buy other pig iron for conversion into steel. In order to remove these anomalies the Ministry proposed to allow the freight rebate on all iron ore imported from Spanish and Mediterranean ports without restriction as to use—whether for hematite pig iron or basic pig iron, for steel or for spiegel-eisen—and, irrespective of the fact that some small portion of the product might eventually be sold at uncontrolled prices.

The proportion sold at uncontrolled prices would be trifling. The prices of hematite and basic pig iron and of various classes of steel for home consumption were already controlled, and there would be no difficulty in fixing a maximum price for spiegel-eisen.

The Treasury felt that the necessities of the case compelled them to accept the Ministry's scheme in spite of the strong theoretical objections to it (23 May, 1917),[2] but urged that a close watch should be kept upon exports of steel and iron to neutral countries for general purposes, as, though the exports were small at the moment (averaging about 100,000 tons per quarter to the Colonies and neutral countries out of a total steel export averaging 360,000 tons per quarter), the new scheme would tend to make such exports more profitable.

The decision that the Government would pay freight rebates on all ore imported from the Mediterranean and from Spain was communicated to the steel makers and to makers of pig iron on 31 May.[3] Any saving or excess on the parity rates was to be credited or debited to the Ministry of Munitions, and it was explained that an arrangement was being introduced by which the importer would only pay the parity rate and meet the balance by a cheque on the Ministry

[1] M.F./Gen./546.
[2] 16866/17 in M.F./Gen./546.
[3] M.F./Gen./546.

of Munitions. A circular issued on 15 June announced that the balance of freight over parity would be paid by the shipping agents of the Ministry.[1]

In view of the fact that under the new system the Ministry paid all freight charges above parity, the rebate of 3s. 9d. and 3s. per ton upon ore would be abolished, and it was decided (31 May), subject to Treasury approval to convert these rebates on ore into subsidies on iron at the rate of 7*s.* 6*d.* and 6*s.* per ton on home deliveries of East Coast hematite pig iron.[2]

Treasury approval was obtained, and with the concurrence of the Ministry of Shipping, the new system of payment for iron ore freights was introduced in June, 1917. The ships' agents collected the parity rate of freight from the receiver of the cargo, the excess being paid by demand drafts issued by the Overseas Transport Department's agents at the various ports and drawn upon the Paymaster-General. This new arrangement relieved the Finance Branch of much of the work of adjustment of parity and chartered rates, and was also a boon to the ironmasters, many of whom stated that they were unable to continue to advance money for, or await repayment of, the high freights demanded for neutral ships.

Another system of rebates, applied to iron ore briquettes from the Sydvaranger mines in Norway, was sanctioned by the Treasury on 8 July, 1916, in order to enable makers to sell iron made from these briquettes at the controlled price.[3] A further financial responsibility—not, however, of a very important character—undertaken by the Ministry in order to prevent a rise in prices, was the payment of a rebate on the freight of certain coal supplied to Spanish railways in order to ensure transport of essential supplies.[4]

The scarcity of neutral tonnage for iron ore importation led to two other arrangements involving a burden upon the Treasury being adopted. By agreement with the French and Italian Government, French and Spanish ships engaged in carrying coal from Great Britain were made available for bringing iron ore to Great Britain, any financial loss being met by the Ministry. These schemes were sanctioned by the Treasury on 1 January and 17 January, 1917.[5] By the second arrangement, which is considered in more detail elsewhere, the Treasury sanctioned the insurance by the Government of cargoes of iron ore carried in neutral ships (10 March, 1917).[6]

The cost of the freight rebates was formidable. In November, 1917, it was estimated that the excess freights, including war risk

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[1] M.F./Gen./546.
[2] Meeting on 31 May. (M.F./Gen./546.)
[3] C.R. 3263.
[4] C.I.S.P./Gen./8. As from 1 April, 1918, importers of iron ore were repaid any difference in the Spanish exchange between 19·50 pesetas to the £1 and the ruling rate. (M.F./Gen./1455.)
[5] M.F./Gen./228.
[6] *Ibid.*

insurance, amounted to 30s. per ton, but by April, 1918, the estimate had risen to £4 5s. per ton on ore imported from Spanish and Mediterranean ports. On imports averaging 450,000 tons per month excess freight and insurance cost about £23,000,000 yearly.

(c) Fixing Prices of Iron Ore.

The question of settling a maximum price for iron ore was taken in hand at the end of 1915, the case of West Coast hematite ore arising first. At a meeting on 9 December, 1915, the mineowners pointed out that wages had increased by 67 per cent. and that royalties had also risen. They agreed to the fixing of a maximum price equal to the average price for October and November (when prices were about 6s. higher than in September), less 2 per cent. The controlled price only referred to the ordinary hematite ore which was divided into three grades; (1) the best (Hodbarrow) ore, for which it was suggested prices should range from 33s. to 38s.; (2) second special quality 28s. to 33s.; (3) ordinary up to 28s. The price was fixed by Sir W. Peat after inspecting the books.[1]

The ironmasters acknowledged that these prices formed a fair average. Local ores were undoubtedly more refractory and difficult to deal with than the average Spanish imported ore, and it was felt that in this respect ironmasters on the East Coast (where all ore came into port) had the advantage over the West Coast. In April, 1916, the West Coast iron ore mineowners asked for an increase of $2\frac{1}{2}$ per cent. and it was decided to confer with the pig iron makers and consider the alternative of decreasing the price of pig iron.[2]

In July, 1916, in order to increase production, a rebate on royalties was introduced. The miners' representatives offered to work extra shifts on condition that royalties were limited, and on 19 July the owners agreed to reduce their royalties on all ore won during the extra shifts.

Throughout the first half of 1917, there was considerable trouble with the Cumberland iron ore miners, which resulted, on 24 July, in the Ministry taking over the iron ore mines of Cumberland and Lancashire under Regulation 9 G.G. of the Defence of the Realm Regulations guaranteeing the owners a standard rate of profit based on pre-war earnings, with an allowance for dilapidation. By a supplementary agreement the payment of standard profit was to be free of excess profits duty.[3]

Further labour difficulties were caused by the transfer of Scotch miners to Cumberland in October, 1917.[4] In April, 1918, there was an enquiry into the financial results of this action,[5] and the Committee

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[1] The price was not to apply to lumpy ore or that used for annealing.
[2] (Printed) *Weekly Report*, No. 38, III. F. (22.4.16).
[3] F.A.6/Gen./5.
[4] M.W. 138574; M.C. 131.
[5] M.S. 22797.

on Costs of Production reported in June, 1918, that the majority of the mines showed a loss, after crediting iron masters with the output at selling prices. A loss of £48,172 had been incurred in six months' working, which would be increased when the standard profits were paid to the mine owners, and the committee thought there should be some other standard of profit or loss than that which had been adopted. On the other hand, the cost of production of the ore would probably be less than the landed cost of foreign ore.[1] It was realised of course, that as long as the mines were worked at a loss the Ministry was subsidising the iron and steel industry to the extent of that loss, which was estimated at £640,000 a year,[2] but in view of the necessity of obtaining the highest possible output of home ore this loss had to be faced.

Meanwhile the price of Spanish ore had been rising, and on 24 October, 1916, the Iron Ore Merchants' Advisory Committee was summoned to a conference on the best means of checking the rise. It was stated that as much as 30 pesetas per ton had been paid f.o.b. Bilbao for 1917, and it was expected that prices would rise to 40*s*. per ton c.i.f. On 16 January, 1917, it was decided that the purchase of Spanish ore by local committees was to be made at a price not exceeding 41*s*. per ton for best Bilbao. This was raised later to 43*s*. 6*d*., of which 17*s*. was freight. The Spanish merchant, therefore, received 26*s*. 6*d*. per ton, which, taken at an average exchange of 18 pesetas to the £1, gave him 23.8 pesetas per ton. As has been seen, the pre-war price was 22.3 pesetas, so that the price in Spanish currency had remained practically at the pre-war level. This, as Mr. Guedalla pointed out (29 July, 1918), reflected great credit on the organisation dealing with the importation of foreign ore, even taking into consideration the cessation of export from Spain to Germany.

III.—Coke.[3]

Another governing factor in the cost of production of steel and pig iron was the price of coke. It took, roughly, 22 cwt. of coke to make one ton of hematite pig iron and 35 cwt. of coke to make one ton of basic pig iron. About 15 cwt. to 25 cwt. of coal had to be used with either class of pig iron to produce one ton of steel, while it took one and a half tons of coal to make one ton of coke. The iron and steel industry in 1918 was consuming coal and coke at the rate of about 31,000,000 tons per annum.

The price of coke had fluctuated violently in 1915. The average pre-war price was about 22*s*., but owing to a glut of coke, due to the erection of large plant for the manufacture of toluol, prices fell to about 17*s*. or 18*s*. in the early months of 1915. In June the prohibition of export was relaxed. South Yorkshire coke rose from 18*s*.

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[1] M.F./Gen./1636; D.F.3/Cap.Exp./24; C.F.A.C./Gen./1.
[2] HIST. REC./R./661/22.
[3] HIST. REC./R./661.1/6, 3; Sir L. Llewelyn's Papers, 158.

and 19*s*. to 27*s*., and by November, Durham coke was being sold at 40*s*. a ton. Makers of pig iron were unable to get coke, while it was being freely exported at high prices. Attempts were made in December, 1915, to control first the supply and then the price. Local Coal and Coke Committees were set up in eleven districts, reporting to a Central Coal and Coke Committee representing the various departments interested. On 13 December export was limited, and permission to export was only given after local requirements had been met.

Conferences with representatives of the coke industry were held in December with the object of fixing maximum prices for the three classes of coke—blast furnace, foundry and special. Coke manufacturers complained of shortage of labour, due to enlistment, of the rise of wages and freights, of the high price of slack, sulphuric acid, and other stores, and of increasing depreciation of plant. It was found to be impossible to fix uniform prices that would hold good throughout the country owing to the different conditions of manufacture. In South Wales for instance, 50 per cent. of the ovens were of the old fashioned beehive type, in other districts there were profitable by-product ovens, or coke ovens owned by colliery proprietors. Different prices were fixed by voluntary agreement in the various districts; they were published in April, 1916, and were to apply until 30 June, 1916.

But, by June, all the local associations of coke producers were asking for an increase of price owing to increased cost of labour and material. The Welsh coke producers, interviewed on 24 June and 30 June, claimed an extra 3*s*. a ton under their sliding scale, as miners' wages had risen 15 per cent since their December agreement. They also argued that the high profits made by the steel makers entitled them to an increase. The Ministry, however, induced them to forego this sliding scale arrangement; blast furnace coke was to remain at 30*s*. until the end of 1916, and the price of foundry coke was to rise by 3*s*.

The Yorkshire manufacturers had been granted an increase of 1*s*. 8*d*. per ton in the beginning of June, and the Midland manufacturers obtained an increase of the same amount. The maximum price for Durham and Northumberland coke remained unaltered.

In order to prevent evasion of the agreed prices, metallurgical coke, in common with pig iron and steel, was placed under Regulation 30A, in July, 1916, and the maximum prices were given a legal sanction.[1]

The same scale of prices was confirmed in November, 1916, and remained in force till November, 1917, when a fresh scale, which included Scottish coke, was introduced, as a result of the Coal Controller's award.

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[1] A.M.2/536.

The following table shows the maximum prices which were fixed at these various dates :—

District.	Type of Coke.	December, 1915.	July and November 1916.	November, 1917.
		£ s. d.	£ s. d.	£ s. d.
Durham and Northumberland.	Blast Furnace ..	1 8 0	1 8 0	1 13 0
	Foundry	1 10 6	1 10 6	1 18 0
Lancashire	Blast Furnace ..	—	1 5 8	1 12 0
Midland Counties ..	Blast Furnace ..	1 4 0 at the ovens	1 5 8	1 12 0
S. Wales and Monmouthshire.	Blast Furnace ..	1 10 0 and 1s. per ton for every 5% increase on miners' wages.	1 10 0	1 17 6
	Special Foundry	2 0 0 1s. per ton for every 5 % increase on wages.	2 3 0	2 10 6
South Yorkshire ..	Special Foundry	1 4 0 at the ovens.	1 5 8	1 12 0
West Yorkshire ..	Special Foundry	1 4 0 at the ovens.	1 5 8	1 12 0
Cumberland	Blast Furnace ..	25% of price of pig iron.	25% of price of pig iron.	1 17 9
Scottish	Blast Furnace ..	—	—	1 15 0
	Foundry	—	—	2 5 0

IV.—Pig Iron.

(a) Control of Prices by Agreement.

If steel makers were to carry out their agreement with the Ministry it was clear that the rise in the price of pig iron, which by November, 1915, varied from 19s. to 66s. per ton according to the district, must be kept within reasonable limits. It is necessary from the outset to distinguish between the ironmasters of the North East Coast, North West Coast, South Wales and Scotland, who were makers of hematite iron, and the ironmasters of Cleveland, the Midlands, Lincoln and North and South Staffordshire who made forge, foundry and basic iron, as the financial arrangements varied with each group and district.

The Ministry first adopted the policy of fixing by agreement with representatives of the trade maximum prices based upon the cost of production, allowing a fair margin for profit. Where agreement was impossible, or insufficient evidence as to costs was produced, an arbitrator was authorised to examine the books and to fix a maximum price based on the average profits of the last two or three years. There were, however, few cases in which it was found necessary to resort to this expedient.

After conferences with the West Coast ironmasters, the price of 127*s.* 6*d.* for ordinary mixed numbers, 135*s.* 6*d.* for ·02 sulphur and phosphorus, and 148*s.* for ·03 sulphur and phosphorus were adopted on 15 December. A few days before, on 8 December, the East Coast ironmasters had accepted £6, based on ore at 34*s.* and coke at 30*s.*

The check to the rise in the price of ore effected by the Ministry accepting the responsibility for the payment of all freights over 17s. cleared the way for similar agreements with the ironmasters of Scotland and South Wales. The high freights ruling for the transport of limestone from Wales to Scotch ports were a special grievance of the Scottish ironmasters, and in order to induce them to accept a scale of prices for hematite pig iron uniform with those proposed for the English districts, the Ministry agreed to relieve them of the difference between pre-war and existing freights on iron ore and limestone (29 March, 1916). The rate of rebate on iron ore was to be the monthly average excess freight paid over the fixed parity rates for the various ports, and the rate of rebate on limestone was to be the monthly average excess freight paid over the average freight during the six months ending 31 July, 1914.

The tonnage on which rebate was payable was the amount of iron ore and limestone required to make the quantity of pig iron sold at the maximum price, on the following basis :—

(*a*) two tons of iron ore to one ton of hematite pig iron.
(*b*) 10 cwts. of limestone to one ton of hematite pig iron.
(*c*) the actual quantity of ore used in the production of foundry or forge pig iron.

Treasury sanction for the freight rebate was obtained on 18 May, and for the limestone rebate which it was estimated would cost £900 a month (6s. per ton on 3,000 tons), on 13 September, 1916.[1] The agreement further secured the ironmaster against a rise in the price of Spanish ore.[2]

Negotiations on the same lines followed with the Cleveland, Lincolnshire, Midland and Staffordshire groups of ironmasters—the makers of basic and forge and foundry iron—all of whom pressed for high prices owing to high costs of production. Trade jealousies were a constant hindrance to negotiations. The ironmasters maintained that the steel makers were making profits of 125 per cent. and

[1] 10,223/16 and 9,792/16 in A.M.2/265.
[2] 9279/17 in D.F.1/Claims/2.

that they alone were interested in fixing the price of pig iron. There were many complaints of a shortage of coke and that coke makers were exporting their product at a high profit.

The outcome of these intricate negotiations may be seen in the accompanying table :—[1]

Name of Association or Group of Ironmasters.	Date of Agreement.	Agreed maximum price.
Hematite Iron Makers		
N.E. Coast	8 December, 1915..	£6, based on ore at 34*s.* and coke at 30*s.*
	28 & 29 March, 1916	£6 2*s.* 6*d.*, based on ore at 34*s.* and freight at 17*s.*
West Coast	15 December, 1915..	£6 7*s.* 6*d.* to £7 8*s.* 0*d.*
	22 March, 1916 ..	Agreement renewed for 3 months at £6 2*s.* 6*d.*, based on freights at 17*s.*
South Wales.. ..	14 March, 1916 ..	£6 2*s.* 6*d.*, based on freights at 17*s.*
Scottish	28 and 29 March, 1916.	£6 2*s.* 6*d.*, based on freights at 17*s.*, and ore at 34*s.*
Non-Hematite Iron Makers.		
Lincolnshire ..	21 December, 1915	£4 15*s.* 0*d.*
Midland	6 January, 1916 ..	£4 2*s.* 6*d.* to £4 17*s.* 6*d.*
North Staffordshire..	29 December, 1915	£4 15*s.* 0*d.*
South Staffordshire..	6 January, 1916 ..	£4 5*s.* 0*d.* to £4 17*s.* 6*d.*
Cleveland	10 March, 1916 ..	£4 2*s.* 6*d.* with coke at 30*s.*

A Press announcement of 6 April, 1916, gave official intimation to the trade of the maximum prices fixed, but this system of fixing prices by voluntary agreement soon broke down, and complaints of excessive charges reached the Ministry soon after the publication of the agreed prices. The maximum price had everywhere become a flat rate, and in many cases makers were refusing to sell at the maximum prices, and obtaining a premium.

At the same time a serious prospective shortage of pig iron became apparent. The Ministry decided that 50 idle blast furnaces must be started up at once (17 May, 1916),[2] and the ironmasters' demands for an increased price therefore met with sympathetic consideration. In three of the districts increased prices were agreed upon, and negotiations with the Scottish ironmasters were in progress when the Ministry decided upon a considerable change of policy. It was realised that owing to the increased demand the agreed maximum prices were being evaded in all directions. Pig iron was being sold for as much as £8 a ton in Wales, the makers relying on the inability of the Ministry to

[1] Sir L. Llewelyn's Papers, 158, 158A.
[2] Sir L. Llewelyn's Papers, 158A.

enforce the maximum prices, and it was recognised that the system of attempting to control prices by voluntary agreement had broken down.[1]

(*b*) Control of Prices under Regulation 30A.

It was therefore decided to place steel, iron and coke under Defence of the Realm Regulations 30A, thus forbidding any dealings in those materials without a permit from the Admiralty, Army Council or Minister of Munitions. An order to this effect was issued on 7 July, and a general permit to deal in iron and steel products was issued provided that the maximum prices fixed under a schedule attached were not exceeded, and that the rules laid down by the Ministry as to the disposal of the materials were obeyed.

Except by special permit from the Ministry the maximum prices laid down might only be exceeded in the case of :—

(*a*) sales of quantities below 5 tons.
(*b*) finished steel rolled from steel bought by the seller.
(*c*) material sanctioned for export.[2]

(*c*) Keeping Prices Fixed by Subsidy.

The maximum prices thus fixed under the Defence of the Realm Regulations had a legal sanction and could not be evaded without penalty. The Ministry, however, soon found itself faced with the difficulty that these prices did not really repay the ironmasters for increasing costs of production. At the same time it was absolutely necessary that there should be no decline of output.

The Ministry had to choose between raising the maximum prices and subsidising the makers to continue production on the largest possible scale, and for reasons already discussed, it decided in the case of hematite iron to subsidise the trade where necessary, and to allow a rise in prices in the case of non-hematite iron.

The arrangements varied in the different districts. In order to make the position as clear as possible it is advisable to treat the four chief groups of makers of hematite iron separately, and then pass to the arrangements with makers of other classes of pig iron.

(1). *The North West Coast Group.* In addition to the rebate on freights obtained in March, 1916, and on war risk insurance in January, 1917, this group obtained a series of concessions to meet increased costs of production.

Owing to the frequent diversion by the Overseas Transport Department of ore steamers to less congested ports in order to obtain quicker discharge, the ore often had to be carried long distances by rail. In order to meet this hardship, the Ministry agreed to repay to the

[1] A.M. 2/265. [2] A.M.2/595.

ironmasters the railway freight in excess of that which would have have been paid if the cargoes had been delivered at the usual ports, this rebate being payable from 1 January, 1917. Further in order to meet increased costs of production the ironmasters of this district obtained a rebate of 5s. per ton of ore imported from Spanish and Mediterranean ports. This rebate dated from 1 July, 1917, and when on 25 January, 1918, the price of these ores was increased by 2s. 6d., the rebate to the ironmasters was increased to 7s. 6d. per ton of ore.

By the Spanish exchange scheme, which was designed to check the heavy fall in the value of the £1 sterling,[1] the man who sold ore in Spain added to his price the difference in exchange between the fixed rate of 19.50 pesetas to the £1, and a daily exchange fixed by Mr. Macleod of the Steel Production Department. The Ministry under took to repay this extra cost from 1 April, 1918.

In order to meet the cost of the Coal Controller's award a subsidy of 9*s*. 6*d*. was granted on each ton of pig iron delivered at or under the controlled prices, the subsidy to date from 18 September, 1917.

The other disturbing factor, the awards of increased wages by the Committee on Production, had also to be met, and in July, 1918, negotiations were in progress for making a definite allowance on each ton of pig iron produced to meet the increased cost of labour, 9*d*. per ton being suggested as a possible figure.

(2) *The Scottish Group*.—Like the North West Coast Group the Scottish Group was given the rebates on freight and on war risk insurance, and the extra cost of the Spanish exchange scheme, but the arrangements for obtaining a repayment of part of the price of foreign ore were different from those in force on the North West Coast. As has been seen, Scottish iron masters were repaid any excess cost of Spanish ore over 34*s*., which was equivalent to a rebate of 7*s*. at the price of 41*s*. In addition they obtained rebates on seaborne limestone freights from March, 1916, and on railborne limestone freights from 1 July, 1916, the basis of the latter being to ensure that the cost of English limestone at the Scotch furnaces should not exceed the cost of Welsh limestone after crediting the freight rebate.

In August, 1916, the Scottish ironmasters resumed their agitation for further concessions. Their case was admittedly a hard one. Some of them had been urged to re-start furnaces which were out of date and unprofitable, others were hampered by their geographical position and the high cost of fuel. Scotch and North East Coast hematite were of the same value in steel making, but owing to the high cost of carriage, etc., the price of the Scotch iron had always been from 4*s*. to 6*s*. higher. The fixed price of £6 2*s*. 6*d*., therefore, placed Scotch makers at a disadvantage.

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[1] The par value of the £1 sterling was 25·225 pesetas. By June, 1917, the exchange was 20·425 pesetas, a premium of 19 per cent. for Spanish currency over British, which before the war was at a premium of 10 per cent. The exchange question was discussed by the Financial Advisory Committee in July, 1917, but the Ministry did not interfere until 1918.

An investigation of the costs submitted, however, showed that no firm was actually working at a loss. The worst case was that of a firm making a profit of 3*s*. 6*d*. a ton, and the Finance Department contended that the majority of the firms were getting 10 per cent. on the capital invested, though this was not admitted by the Association. After a deputation of ironmasters had been received by the Minister a provisional agreement was reached. The whole matter was fully discussed with the Treasury, and in view of the danger of furnaces being allowed to go out of blast at a time when every ton of pig iron was urgently wanted, the Treasury gave preliminary approval to the scheme (4 September).

The scheme was embodied in a formal agreement dated 24 November, 1916, under which the Scottish ironmasters received a grant equivalent to any excess in the price of imported iron ore beyond certain standard amounts, viz., 30*s*. 3*d*. per ton for best Rubio ore f.o.t. Scottish ports used in the manufacture of hematite pig iron or steel sold at or below the maximum prices, and 30*s*. per ton for best Rubio ore f.o.t. Scottish ports, used in the manufacture of foundry and forge pig iron sold at or below the maximum prices.[1] This meant a rebate of 3*s*. 9*d*. on the ruling price of Spanish ore in the case of hematite pig iron. As it was reckoned that two tons of ore were required to make one ton of iron, the ironmasters received a rebate of 7*s*. 6*d*. on every ton of iron produced and sold at the maximum price. In order to safeguard the liability of the Treasury in respect of these rebates on ore a Committee of Iron Masters under the chairmanship of a representative of the Ministry of Munitions was appointed to prevent reckless buying of ore, the chairman having the power of veto.

The agreement also provided for a minor difficulty—the reluctance of the ironmasters to make provision for adequate supplies of ore and limestone, as they feared being left at the end of the war with heavy stocks bought at inflated prices. The Ministry, by Clause 8 of this agreement, undertook to buy and the ironmasters undertook to sell at the maximum price the whole output of pig iron for four months after notice to terminate the agreement had been given, the ironmasters being entitled to the agreed rebate. The Treasury, while prepared to sanction the general lines of the agreement, hesitated over this clause (15 December, 1916), but on being informed by the Ministry (2 January, 1917) that in the event of the sudden cessation of hostilities, the loss would probably not exceed £300,000, decided to sanction it (11 January, 1917).[2]

As the price of Spanish ore rose, the rebate received by the Scottish iron masters increased. By January, 1918, the rebate amounted to the difference between 30*s*. 3*d*. and 41*s*., viz., 10*s*. 9*d*., which was increased

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[1] The formal sanction of the Treasury was given on 15 December, 1916. (32228/16 in A.M.2/343.)

[2] The Steel Department estimated the fall in the market value of pig iron at 20*s*. per ton, and the period during which any loss could be sustained was limited under the agreement to four months, during which the Scottish output of hematite pig iron would not be more than 300,000 tons. (A.M.2/343.)

to 13*s*. 3*d*. when the price of Spanish ore rose to 43*s*. 6*d*. on 25 January, 1918. When the rebate system was abolished (May, 1917), these rebates of 3*s*. 9*d*. and 3*s*. a ton on ore were converted into subsidies of 7*s*. 6*d*. and 6*s*. a ton on pig iron manufactured and sold at maximum prices. These alterations took effect as from 1 April, 1917, and October, 1917.[1]

By 30 June, 1917, therefore, the subsidies paid by the Ministry (7*s*. 6*d*. and 6*s*. and 30*s*. excess freight) on the production of one ton of pig iron amounted to £2 3*s*. 6*d*., which might be calculated as equal to a subsidy of £2 5*s*. 0*d*. a ton on the price of steel, reckoning rather more than one ton of pig iron to the ton of steel.

The Coal Controller's award and the 12½ per cent. award rendered a further variation of prices necessary, and the draft agreement with the Scottish iron masters (25 April, 1918), included additional subsidies amounting to 7*s*. per ton on iron, made after 17 September, 1917, 3*s*. per ton on iron made after 31 December, 1917, together with a subsidy of 3*s*. 6*d*. per ton on raw native limestone, and of 5*s*. 3*d*. per ton on calcined native limestone.

(3) *The North East Coast Group*.—This group, like the others, received freight rebates, war risk insurance rebates, and Spanish exchange rebates.

The method of meeting increased costs of production on the North East Coast was different from that adopted elsewhere. The North East Coast ironmasters received no rebate on the price of ore beyond the freight rebate of March, 1916, until 25 January, 1918, when they received 2*s*. 6*d*. a ton to meet an equivalent rise in the cost of Spanish ore. In lieu of a rebate on the price of ore, however, they received from 1 October, 1916, a subsidy of 7*s*. 6*d*. on every ton of hematite iron they produced. This subsidy was increased on 1 April, 1917, to 13*s*. 6*d*. a ton, and on 18 September to 20*s*. a ton, to meet the Coal Controller's award. In July, 1918, negotiations were proceeding with a view to compounding the 12½ per cent. advance to time workers and the 7½ per cent. to piece workers for 9*d*. per ton of iron.[2]

(4) *The South Wales Group*.—The freight rebates, war risk insurance rebates and Spanish exchange rebates, applied to this as to the other four groups of hematite iron makers.

From 1 September, 1916, an extra rebate on ore was granted equivalent to the difference between the cost of foreign ore delivered at Welsh ports (after deduction of the freight rebate payable) and 34*s*. per ton. The excess was in no case to exceed 4*s*. 6*d*. per ton. This arrangement received Treasury sanction on 15 December, 1916.[3] It was reported on 13 January, 1917, that the South Wales Group had repudiated this arrangement, and that new terms had been made which would have the effect of reducing the rebate payable,[4] but

[1] M.F./Gen./546.
[2] A.M.2/265; HIST. REC./R./661/22.
[3] 32228/16 in A.M.2/343.
[4] (Printed) *Weekly Report*, No. 75, XI (13.1.17).

nothing seems to have come of this, and when the price of Spanish ore rose to 43*s*. 6*d*. (26 January, 1918) an additional rebate of 2*s*. 6*d*. was granted as in the case of the other three groups. The Coal Controller's award was met by a subsidy of 9*s*. 6*d*. a ton on deliveries of iron from the South Wales district, to date from 18 September, 1918. In July, 1918, negotiations were in progress for refunding to the ironmasters the increased cost of wages under the Government awards.

The following summary shows how the various rebates and subsidies already referred to operated in the four districts, and the extent to which the production of hematite pig iron was subsidised in July, 1918.

At that date the following rebates and allowances on foreign ore were being paid :—

	N.E. Coast.	N.W. Coast.	S. Wales.	Scotland.
	£ *s*. *d*.	£ *s*. *d*.	£ *s*. *d*.	£ *s*. *d*.
Excess in parity rate of freight, including insurance of hulls.	4 0 0	4 0 0	4 0 0	4 0 0
Increase in price of ore ..	0 2 6	0 2 6	0 2 6	0 2 6
Subsidy on foreign ore ..	—	0 5 0	—	—
Difference in price of ore ..	—	—	0 7 0	0 10 9
Totals	£4 2 6	£4 7 6	£4 9 6	£4 13 3

In order to interpret these subsidies on foreign ore in terms of pig iron, two tons of ore were reckoned as equivalent to one ton of pig iron, except in the North West district, where 15 cwts. only of foreign ore were used with the home ore. The total subsidy per ton of pig iron, therefore, may be summarised as follows :—

	N.E. Coast.	N.W. Coast.	S. Wales.	Scotland.
	£ *s*. *d*.	£ *s*. *d*.	£ *s*. *d*.	£ *s*. *d*.
Subsidy on foreign ore per ton of pig iron.	8 5 0 (40 cwts. of ore=1 ton of pig iron).	3 5 9 (15 cwts. of ore=1 ton of pig iron).	8 19 0 (40 cwts. of ore=1 ton of iron).	9 6 6 (40 cwts. of ore=1 ton of iron).
Subsidy on pig iron ..	1 0 0	0 9 9	0 9 6	0 10 9
Loss on working Cumberland ore mines (4*s*. per ton and 25 cwt. per ton of iron).	—	0 10 0	—	—
Increased wages 12½% and 7½%	0 5 0	0 1 6	0 5 0	0 5 0
War risk Insurance ..				
Totals	£9 10 0	£4 7 0	£9 13 6	£10 2 3
	tons.	tons.	tons.	tons.
Approximate weekly output	20,000	25,000	16,000	12,500

From these figures it appears that on a total production of 73,500 tons of pig iron, an average subsidy of £7 18s. 0d. per ton was paid.

While the negotiations with the hematite pig iron makers had resulted in the payment of rebates and subsidies the increased costs of the makers of non-hematite iron were met (before September, 1917) by an increase in the maximum prices sanctioned on 7 July, 1916.

Thus, on 15 August, 1916, a new schedule was issued, which added 5*s.* to the maximum prices of Lincolnshire, Northamptonshire, North Staffordshire and South Staffordshire forge and foundry iron.[1] After some delay the Midland Association of Blast Furnace Owners accepted a similar increase of 5*s.* per ton on Derbyshire, Leicestershire and Nottinghamshire brands, and a schedule giving the revised prices was issued on 13 September.[2] The Cleveland iron makers obtained a 5*s.* advance in price on 17 July, 1917, and the South Staffordshire makers a further advance of 5*s.* at the same date.

It was not until the Coal Controller's award was made in September, 1917, that the principle of giving subsidies to makers of non-hematite iron was admitted. The subsidies given as a result of that award appear, together with the variations in the controlled price after July, 1916, in the following table :—

	1916. July.	1916. August.	1916. November.	1917, July.	1917, November.	Subsidy to meet Coal Controller's Award.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Cleveland Pig Iron ..	4 11 6	4 11 6	4 11 6	4 16 6	4 19 0 Other grades £4 15*s.* and Basic £5.	0 11 6
Derbyshire .. Leicester .. Nottingham .. Lincolnshire . Pig-Iron (Basic and Foundry).	4 5 0 / 4 7 6	4 5 0 / 4 12 6	4 10 0* / 4 12 6	4 10 0 / 4 12 6	4 10 0 Forge. / 4 16 6 Foundry.	0 18 0 / 0 11 6
Northamptonshire ..	4 2 6	4 7 6	—	—	—	0 18 0
North Staffordshire 1	4 10 0	4 15 0	—	—	—	1 0 0
North Staffordshire 2	4 12 6	4 17 6	—	—	—	
North Staffordshire 3	4 15 0	4 17 6	—	—	—	
South Staffordshire, Shropshire and Worcester—Cold blast.	4 10 0	4 15 0	—	5 0 0	—	Cold blast 0 7 6 Other grades, 1 0 0
Bar Iron— (Marked bars) ..	15 0 0	15 0 0	—	—	—	—

[1] Forge. [2] Foundry. [3] Basic. * 13 September.

(*d*) The Guaranteed Profit Scheme for Basic Iron.

In view of the extreme urgency of increasing the output of pig iron from home ores at the beginning of 1917, the Steel Production Department evolved a guaranteed profit scheme in order to encourage production by iron masters who had furnaces more or less derelict, or whose furnaces would have to be converted to use basic ores.[3]

[1] A.M.2/660.
[2] *Ibid.*
[3] 11 April, 1917. (M.F./Gen./465.)

It was not considered advisable to pay the firms a fixed percentage of profit based either on their actual cost of production or on the fixed selling price, as such an arrangement would be no inducement to economical production. Under a scheme outlined on 11 April, 1917, 10 per cent. of the selling price was regarded as a fair profit and firms making this amount of profit would not be helped. The scheme was designed to give other firms a profit at a reasonable cost, their profit to diminish as their cost of production increased, and it was proposed that the total subsidy given by the Ministry should be limited to 20*s.* per ton.

Sir John Hunter endorsed the scheme and forwarded it to Mr. Mann for approval on 11 April. Two days later (13 April), Treasury approval was sought, the concrete proposal being that the Ministry should be empowered to guarantee to firms undertaking to use native ores the cost of production actually incurred up to a limit of 14*s.* per ton of pig iron above the maximum price fixed for sale, and in addition to guarantee a minimum profit of 6*s.* per ton, rising to about 7*s.* 6*d.* a ton, as the cost of production diminished and approached the maximum selling price. Where the cost of production was below the maximum sale price, it was proposed to guarantee a 10 per cent. profit on that price. The Treasury was informed that the maximum liability to the Exchequer would amount to 20*s.* per ton of pig iron produced, and that in Dr. Addison's opinion, it was expedient to agree to pay this sum if necessary rather than increase the fixed maximum selling price. It was impossible to estimate the amount which might become payable under the proposed guarantee, but it was not expected that more than 1,000,000 tons of basic pig iron could be produced from the furnaces during any one year. The furnaces were situated in different parts of the country, but did not include any furnaces in the Cleveland and Cumberland districts which were using a different kind of ore. Some further expenditure on overhauling and repairing furnaces would be necessary, which it was proposed to meet by a writing off in the accounts of the companies as controlled establishments, or by a small supplementary grant. It was not anticipated that this would involve more than a comparatively small sum of money.

The whole scheme was to be subject to termination by the Minister at any time after giving a fortnight's notice. It was sanctioned by the Treasury on 23 April,[1] and on the same day, a circular letter was sent to the iron masters outlining the scheme, which was to apply only to iron masters who were not also steel makers and in respect of sales of basic pig iron to other companies.[2]

When the maker produced pig iron at a profit of 5*s.* a ton the Ministry added an allowance of 3*s.* 4*d.*, making the total profit 8*s.* 4*d.* When profit of 1*s.* a ton only was made, the Ministry added 6*s.* 8*d.*, making the total 7*s.* 8*d.*, and so on down the scale, the allowance by the Ministry increasing, but the total retained by the company diminishing with every increase in the cost of production. Thus when

[1] 12398/17 in M.F./Gen./465.
[2] M.F./Gen./465.

the maker made a loss of 12*s.* a ton the Ministry allowance of 17*s.* 6*d.* converted it into a profit of 5*s.* 6*d.*, but the maker who could only produce at a loss of 19*s.* 6*d.* after receiving the maximum allowance of 20*s.* a ton was only 6*d.* to the good. The scale, therefore, stimulated economical production.

In addition to the allowances on the graduated scale, the Ministry stated that any loss incurred owing to the pig iron made from native ores for use in steel making not coming up to the prescribed specification would be refunded to the iron masters up to a maximum amount of 14*s.* per ton of iron, provided the Ministry was satisfied that proper care had been exercised in its manufacture. The loss would be estimated by comparing the selling price of No. 3 foundry iron with the actual cost of production of the basic iron. The Ministry undertook to supply native iron ore, manganese ore and ferro-manganese slag at fixed prices.

These concessions were subject to the companies' accounts being submitted to the Ministry monthly for verification and approval, and the Department reserved the right of terminating the arrangement on giving four weeks' notice in writing, taking over new material at cost price.[1] Fifteen firms were originally included in the scheme, other additions being made later.[2]

(*e*). CONTROL OF BAR IRON PRICES.[3]

At meetings with representatives of the South Yorkshire Bar Iron Association (3 February, 1916), the South Staffordshire Bar Iron Association (23 February), the Scottish Bar Iron Manufacturers (23 February), the fixing of maximum prices was discussed. The makers held out for a high price owing to the high price of coal, the high price of scrap (for which they had to pay £6 10*s.* per ton), and the high price of pig iron, which, though theoretically fixed, could not be bought at the price. The South Staffordshire makers agreed to a maximum price for three months of £13 5*s.* for common bars, and of £14 15*s.* for marked bars. The South Yorkshire makers agreed to £12 10*s.* per ton.

On 30 May the South Staffordshire iron masters applied for an increase in the maximum price. They alleged that their costs had increased by 17*s.* per ton, made up as follows:—

	s.	*d.*	
Pig iron	4	0	
Wages	2	0	
Scrap	6	0	or
	7	0	
Coal	4	3	

[1] One company secured three months' notice as they had to make three months' contracts for materials.

[2] M.F./Gen./465.

[3] Sir L. Llewelyn's Papers, 158, 158A.

Mr. Llewelyn pointed out that the price of pig iron remained unchanged and that the only justification for their demand was the rise in wages.

On 7 July, 1916, the maximum prices of bar iron were controlled by Order, under which standard quality, ordinary sizes and merchants' lengths was to be £13 15*s.* per ton f.o.t., makers' works, and marked bars were to be £15 less 2½ per cent. f.o.t. makers' works. These prices were subject to extras for special sizes and qualities. A sum not exceeding 2½ per cent. might also be added in the case of sales by persons other than the makers.[1] On 15 August a fresh order was issued, under which the price of standard quality remained unchanged, but marked bars were raised to £15 10*s.* per ton less 2½ per cent. f.o.t., makers' works. This increase dated as from 1 August.[2]

(*f*). IRON SCRAP (WROUGHT AND CAST).

When prices were fixed with the Lancashire Association in February, 1916, £5 10*s.* had been submitted as the price of iron scrap, of which 50 per cent. was used for bar iron with 50 per cent. of pig. Early in 1917, as the result of a rise in prices, it became necessary to fix an official maximum price.

By an Order of 22 March, 1917, three grades were recognised:—

(*a*) Wrought iron plate and sectional material ⅜ in.	£6 5 0 per ton.
(*b*) Heavy wrought iron scrap, ⅜ in. thick and over, including horseshoes ..	£5 15 0 per ton.
(*c*) Heavy scrap, ¼ in. thick and over, including heavy country wrought iron scrap	£5 5 0 per ton.

All these prices were f.o.r., or f.o.b., at the nearest siding or wharf to the place where the scrap lay at time of sale. A sum not exceeding 2½ per cent. on such prices might be added in the case of sales by recognised scrap merchants.

The prices and classification of wrought iron scrap were revised under an Order of 28 August, 1917, by which classes (*a*), (*b*), and (*c*) were grouped together under a single class with a common price of £6 5*s.* per ton. Two other classes of scrap were brought under the Regulations. The first, wrought iron scrap mixed with steel or other turnings, was priced at £5 5*s.* per ton. The second, wrought iron turnings and borings mixed with steel and other materials, at £2 10*s.*

The above prices were specifically stated not to apply to heavy forging scrap or to scrap from certain brands of Yorkshire iron.

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[1] A.M.2/536 [2] A.M.2/660.

V.—Miscellaneous Materials.

As part of its general policy of fixing maximum prices for iron and steel, the Ministry had to control the prices of various miscellaneous minerals used in iron and steel production. In some cases the negotiations were long and intricate, but a brief summary will be sufficient for the present purpose.

The price of ferro-manganese was fixed on 12 June, 1915, at £20 a ton, subject to freights, being raised to £25 in February, 1916, owing to the fact that the freight of manganese ore from India had doubled.

The prices of magnesite bricks were regulated in March, 1916, and were based on raw magnesite at 60*s*. per ton. The selling price of 9″ x 4″ x 2½″ bricks was then fixed at £75 per 1,000 net at brick works, and of 9″ x 4½″ x 3″ at £88 per 1,000. Any subsequent rise in magnesite was to be met by an advance of 10*s*. and 12*s*. per 1,000 for the two different sizes of bricks for every 1*s*. rise of magnesite. In consideration of assistance given the Government was to receive an abatement of £5 per 1,000 and £6 per 1,000 respectively.

The price of firebricks, size 9″ x 4½″ x 3″ was before the war 65*s*. per 1,000. The price mounted steadily, reaching 70*s*. in March 1915, 80*s*. in May, 93*s*. 6*d*. in January, 1916, and 100*s*. in May 1916. In August, 1916, the regularisation of prices was taken in hand by the Ministry. The accompanying table shows the maximum prices fixed since that date.

1st grade Stourbridge.	23.8.16.	1.5.17.	17.9.17.
Firebricks, 9 in. × 4½ in. × 3 in. ..	107/6 per 1,000	117/6 per 1,000	137/6 per 1,000
Firebricks, 9 in. × 4½ in. × 2½ in. ..	90/– per 1,000	100/– per 1,000	120/– per 1,000
Furnace linings	55/– per ton	62/6 per ton	70/– per ton
Ground fireclay	20/– per ton	22/– per ton	23/– per ton

Early in January, 1916, as a result of negotiations with the South Wales Silica Brick Association, it was agreed that the basis price of 9″ x 4″ x 2½″ should be £6 per 1,000, delivered in the Swansea and Llanelly districts, or £6 7*s*. delivered in Monmouthshire, marking a rise of some 12 per cent. on pre-war prices. The usual extras were to be charged for other sizes. In the same month the Sheffield makers agreed to a maximum of £6 10*s*. per 1,000 f.o.t. works for the same sized brick. In May, 1916, in consequence of the very serious shortage, the Ministry agreed to raise the price £1 per 1,000 as from 30 June to South Wales and Yorkshire makers on the guarantee of 20 per cent. increased output on that of the last three months.

After August, 1916, prices[1] were revised as follows :—

South Yorkshire Silica Bricks	15/8/16.	7/11/16.	17/9/17.
9 in. × 4½ in. × 3 in.	180/– per 1,000	204/– per 1,000	224/– per 1,000
9 in. × 4½ in. × 2½ in.	150/– per 1,000	170/– per 1,000	190/– per 1,000

[1] f.o.r Maker's works.

VI.—Subsidy Agreements and Wages.

The wages of the majority of the men employed in the iron and steel trades,[1] with the exception of the labourers, bricklayers, blacksmiths and maintenance men, were covered by sliding scale agreements, which showed unusual vitality in these industries. The blast furnacemen, the iron workers, the steel workers and the iron ore miners, together with a proportion of the iron stone getters and the limestone quarrymen, were included, and practically the whole field was covered by Boards of Conciliation. These Boards, which represented employers and men, received reports at intervals—usually every two or three months—on the average selling prices of steel and iron and assessed wages for the next period according to the agreed sliding scale.[2] Thus the wages of iron ore miners, quarrymen in limestone quarries and blast furnacemen followed the fluctuations in the price of pig iron, while those of iron and steel workers followed the variations in the selling price of certain kinds of manufactured iron and steel.[3] Some sliding scales contained a maximum above which wages might not rise.

The effect of the war upon the men employed in these industries was a progressive rise of wages under the sliding scales which was not entirely checked by the fixing of maximum prices. In certain cases the maximum wage limit was altered or withdrawn.[4] Employers pointed out that wages were becoming dangerously high, and that when trade became normal after the war the heavy fall of wages that would of necessity take place would produce ill feeling and destroy the amicable relations that had existed for many years between the masters and men in this trade.[5]

By the end of 1915, wages had already advanced 30 per cent. to 40 per cent., while there were indications that a further 20 per cent. at least would be added during the next few months. Individual manufacturers had no longer such a keen interest in keeping down wages, as they felt that every increase of wages was directly borne by the State, either in the enhanced price paid for the product or by diminishing excess

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[1] In January, 1918, 274,850 men were employed in the iron and steel trades of whom 120,000 were organised in the two great trade union confederations.

[2] *Report on Collective Agreements between Employers and Workpeople.* Cd. 5366 (1910), XXI. *Adjustment of Wages* (1903), by W. J. Ashley, pp. 146–149. *An Iron Trade Sliding Scale.* (*Economic Journal*), March, 1909.

[3] For examples of these sliding scales *see* Cleveland No. 3. Pig Iron Scale (*Report on Collective Agreements*) and the sliding scale based on the selling price of steel rails (where wages were increased one-half of one per cent. for every increase of 6*d.* on the price), *Ibid.*, p. 8, and the scale for puddlers' wages, *Economic Journal*, March, 1909, p. 129.

[4] *e.g.* Award of 20 June, 1916, to iron and steel workers, employed by a certain firm, by which the maximum of 20 per cent. above the base was raised to 60 per cent. In South Wales and Monmouth the maximum limit was withdrawn.

[5] (Printed) *Weekly Report*, No. 25, I (15.1.16); M.W. 70668; 94/S./2846.

profits. Controlled firms were not allowed to alter wages without the consent of the Ministry, but variations under the sliding scale did not require the consent of the Ministry, these advances being covered by the provision in the Munitions of War Act (4, Sect. 2), by which changes according to an agreement made prior to 23 June, 1915, did not require such consent.[1] Mr. Llewelyn thought the effect of the sliding scale agreements on wages in the iron and steel trades had not been fully appreciated when the Act was drafted, and the abnormal increase in wages in the steel trade, might cause unrest in other trades. In his opinion, if the situation were presented to the leaders of the men they would be disposed to take a reasonable view of the matter, and it was quite possible that they would agree that the increase in wages should not exceed, say 50 per cent on the pre-war rates.[2]

Sir Hubert Llewellyn Smith consulted Sir George Askwith on the matter, but he thought that any attempt to suspend the operation of the sliding scales after a 50 per cent. advance on pre-war wages had been reached would be resisted by the men.[3] Again, even if the men agreed to the proposed 50 per cent. limit, such an agreement would become public property and strengthen the agitators in other trades to press for a similar 50 per cent. rise.

Sir George Askwith thought that a severe restriction of prices was a more feasible plan. Sir H. Llewellyn Smith and Dr. Addison agreed that this was the only practicable policy and, as has been seen, one of the motives which induced the Ministry to fix maximum prices was a belief that it would check the advance of wages under the sliding scales. This belief was justified at the outset, and after the fixing of maximum prices wages remained stationary for a time. The agitation for an increase of maximum prices in the autumn of 1916 threatened to set the sliding scales in motion again, and the fact that granting a subsidy to the trade would not necessarily involve the payment of higher wages was a powerful argument in favour of the subsidy system.

This argument, however, was neutralised by a gradual change of opinion. The excess profits duty blunted the employer's interest in keeping wages low, while the competition for labour made him anxious to keep on good terms with his men. As time went on, therefore, it became the custom of the bulk of the employers to inform their men of the existence of these subsidies, and to regard them as an addition to the selling price, which involved a rise of wages under the sliding scales. This practice, however, was not universal, and in some districts subsidies were not allowed to affect wages.

At the same time the workers in the iron and steel trades received various war bonuses by award of the Committee of Production. In January, 1918, it was calculated that the movements in the sliding scales, not including war bonuses, since the outbreak of war, when expressed as percentage increases on the pre-war rate, represented a

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[1] M.W. 70668.
[2] 12 January, 1916.
[3] 26 January, 1916. (M.W. 72453.)

rise of from 42 per cent. to 85 per cent. according to the district in the wages of blast furnacemen, and rises varying from 41·3 per cent. to 85 per cent. in the wages of iron and steel makers.

On 24 December, 1917, the men employed in the iron and steel trades claimed an equivalent to the 12½ per cent. granted to the engineers, foundry and shipbuilding trades. Their representatives definitely stated that " the sliding scales had been rendered inoperative by the fixing of maximum prices," and that in many cases the scale men were in a less satisfactory position than unskilled workpeople who had received full war bonuses, and the men in the engineering trades who had received war wages and war bonuses.

The Ministry dealt with this claim on the following lines. Workers who had received not more than 20s. war advance obtained the advance of 12½ per cent. on their earnings, but in the case of workers who had received war advances in excess of 20s. such excess should merge in the 12½ per cent. on earnings. Any advance accruing under the sliding scales after the date of the settlement was to be merged in any advance arising out of the settlement.

After conferences between the Ministry and the employers and workmen in the iron and steel trades, it was agreed (5 February, 1918), that all subsidies given to the manufacturers since the Coal Controller's award of October, 1917, should be regarded as an advance in the selling price and should affect wages according to the sliding scale. At the same time, all war bonuses given since 1 March, 1917, to meet the increased cost of living were to be merged in the increased wages that resulted from the inclusion of subsidies in the sliding scale price.

This agreement definitely cut away the possibility of arguing that a subsidy was to be preferred to an increase of price owing to the fact that it would not affect wages, and in fact appeared to render any subsequent change of rates under the sliding scales unimportant owing to the 12½ per cent. award.

VII.—Control of Export Prices.

The export price of shell steel for France[1] was controlled at an early date, the price being practically the same as that paid by the British Government, but the prices of exported commercial steel and of pig iron were not controlled until the summer of 1917.

When the Government decided to pay a freight rebate on all imported iron ore, even if it was used for the production of steel or pig iron subsequently exported (23 May, 1917),[2] it became desirable to control the prices of these exports, otherwise the change would mean merely an addition to the iron or steel makers' profits. On the other hand, if the maximum prices ruling for home sales were applied to exports, the Allies and neutral importers would be getting their steel

[1] The price of Italian shell steel was not fixed.
[2] Treasury letter 16866/17 in M.F./Gen./546.

and iron below their commercial value at the cost of the British Government, which paid the rebates.

The Ministry was at first inclined to think that the advantages to be derived from surcharging the export price with a rebate allowance would be more than counter-balanced by the difficulties of assessment and collection (18 May, 1917).[1] It was pointed out that the proportion of steel on which the Ministry would be paying an ore rebate without getting any advantage from it would be very small. The steel exports averaged about 360,000 tons per quarter, of which 260,000 went to Allied countries and 100,000 to Colonies and neutrals. Priority certificates for the Colonies were only given for urgent and important orders, usually for railways, while 40,000 tons were represented by tinplate exports, which were practically for direct government purposes. It was estimated that not more than 10,000 tons per quarter went to neutral countries, and a large proportion of that amount went to railway companies in South America, which the British Government had an interest in keeping going for the transport of food supplies.

The Treasury insisted on the importance of claiming the freight rebates from the Allies (23 May), while urging that an effort should be made to get the Allies to buy steel in America instead of in the United Kingdom, thereby depleting stocks that had to be replaced by Ministry purchases of steel in the United States of America and Canada at high prices.[2] At meetings on 22 and 30 May officers of the Finance, Steel Production and Overseas Transport Departments decided to recommend that the export prices for pig iron and steel should be 15*s.* and 30*s.* higher than the maximum prices for the United Kingdom.[3] Of this extra price a small amount (2*s.* 6*d.* in the case of pig iron and 5*s.* in the case of steel) would be retained by the makers to cover charges for loading for export, etc., but the remainder would be repaid to the Government, as it represented the freight rebates and other charges borne by it.

The steel makers and East Coast hematite makers met at the Ministry on 31 May to discuss this proposal. The pig iron makers argued that if the Government outlay on freight rebates, etc., were included in the price charged for exported iron, it would mean a considerable increase in price and have a very serious effect on wages. It was suggested, therefore, that the export price of hematite pig iron should be £7 1*s.* 0*d.*, calculated as follows :—

	£	*s.*	*d.*
Maximum price for home delivery	6	2	6
Special ore rebate, October, 1916, 8*s.* 9*d.* (converted into subsidy on pig iron)	0	7	6
Special ore rebate, April, 1917, 3*s.* (converted into subsidy on pig iron)	0	6	0
Payment to iron masters covering f.o.b. charges..	0	5	0
	£7	1	0

[1] M.F./Gen./546 ; 94/S./2846.
[2] This topic is dealt with in Vol. II, Part VIII.
[3] *See* Minutes of Meetings in M.F./Gen./546.

The excess freight calculated at 30*s*. per ton was to be charged as a separate item and repaid by the seller to the Ministry, the object being to prevent the export price of hematite being very high and having a serious effect on wages. The suggestion that 30*s*. per ton on pig iron would fairly represent the excess freight paid was confirmed by the Ministry of Shipping (26 June).[1]

The export price for steel was treated in the same way, and the steel makers agreed to charge all steel for export at the maximum prices fixed on 1 November, 1916, and 5 January, 1917, plus 30*s*. per ton. The steel makers pointed out, however, that even with the addition of 30*s*. per ton the export prices for commercial steel were much lower than the prices they had previously obtained, and it was proposed that they should be allowed to keep the 30*s*. per ton in the case of commercial steel repaying to the Ministry 27*s*. 6*d*. of the extra 30*s*. for shell steel.[2]

The Steel Department calculated that this figure of 30*s*. per ton would represent the average of the Ministry's contribution for the manufacture of acid and basic steel taken together, assuming a half and half delivery of each. The charges for the manufacture of basic steel were difficult to estimate, but might be placed at 15*s*., while the subsidies on the manufacture of hematite pig iron amounted to £2 3*s*. 6*d*. per ton, which might be reckoned as £2 5*s*. 0*d*. on acid steel. Thirty shillings, therefore, formed the mean between these figures, and on 14 August the Ministry reported to the Treasury that this figure had been adopted to cover the average excess cost of freight and insurance of raw materials in the case of pig iron, and that 30*s*. per ton would be refunded to the Ministry by the iron masters. The same figure would represent fairly the excess cost of any subsidies and of freight and insurance in the case of steel, but in the case of commercial steel, the home prices of which were admittedly unremunerative, the extra charge of 30*s*. would be retained by the steel makers.

The arrangements for dealing with export prices after the Armistice will be dealt with below.

VIII.—The Cost of the Subsidy System.

The foregoing pages have indicated the difficulty of estimating the real cost of producing the iron and steel sold under the maximum prices fixed by the Ministry, and it was not until July, 1918, that an attempt was made to estimate the actual money cost to the Government of a subsidy system applying to 200 firms excluding the mine owners.

A report by Mr. Guedalla (29 July, 1918) pointed out that subsidies fell into two classes: firstly, the subsidies or rebates on the cost

[1] M.F./Gen./546.
[2] 31 May (M.F./Gen./546).

of foreign ore, its freight, war risk insurance and the Spanish exchange,[1] most of which arose directly out of risks of sea transport in time of war and the cost of which therefore varied as freights rose or fell; and secondly, the subsidies on home production of pig iron and steel which arose from the war increases in the cost of labour and the cost of coal, and which showed a constant tendency to increase.

With regard to the cost of subsidies on hematite pig iron following the ore from the mine to the blast furnace, the charges paid by the Ministry were as follows :—

		Total cost per annum.
(*a*) Differences in the cost of ore, which in some districts were included in the general subsidies. (*b*) Excess war risk insurance over two guineas per cent. from 17 January, 1917, onwards. (*c*) Loss on exchange over 19·50 pesetas to the £1 since 1 April, 1918.	Cost estimated at £250,000 per month.	£3,000,000
(*d*) Excess freights over 17*s.* per ton. Freight averaged approximately 96*s.* per ton before July, 1918, but had dropped to 81*s.* 6*d.* from the Mediterranean and 63*s.* from the North of Spain by the latter date. Every 20*s.* reduction in freight made a difference of £500,000 per month. This fall in freights, however, did not diminish the total subsidy payable, as about 20,000 tons more per week were being imported.	Cost estimated at £2,000,000 per month.	£24,000,000
(*e*) Grants made to certain carrier lines in Spain of part of the freight of the coal imported by them.		£100,000
	Total	£27,100,000

The future cost of (*a*), (*b*), (*c*), (*d*) and (*e*), *i.e.*, the total subsidy payable in future on the importation of hematite ore was estimated (owing to the fall in freights) at £24,651,900 per annum.[2]

The cost of the subsidies payable on the production of pig iron from the subsidised ore, together with the cost of working the Cumberland ore mines at a loss estimated at £640,000 per annum, amounted to £5,541,900 per annum, which brought the total hematite subsidy to £30,193,800 a year.

In addition, the Ministry had granted subsidies on the production of other classes of pig iron and steel. On the importation of American basic pig iron, which was sold by the Government to the manufacturers at the controlled price of 97*s.* 6*d.* per ton, there was a loss estimated at £6 10*s.* per ton. If imported at the rate of 240,000 tons a year this was equivalent to a Government subsidy of £1,560,000 a year on steel made from American iron.

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[1] For the arrangements with regard to the Spanish exchange, *see* M.F./Gen. 1455.

[2] The cost of subsidising the importation of Sydvarangar briquettes and Narvik ores, which was estimated at 10*s.* per ton on 10,000 tons per month, was not taken into account in this estimate.

There were also subsidies on the production of basic iron in the United Kingdom, the cost of which varied in different districts from 20*s.* to 11*s.* 6*d.* per ton. These, together with the sliding scale scheme for stimulating the production of basic iron, might be estimated at £3,000,000 per annum on an output of 67,000 tons of basic iron per week.

The cost of the subsidies on forge and foundry iron, which also varied in different districts, might be estimated at £1,750,000 per annum, and the cost of the subsidy of 15*s.*, a ton on merchant steel payable after 1 November, 1917, at £5,000,000. Further, an allowance had to be made for the cost of the second and third awards of the Coal Controller—(2*s.* 6*d.*, on 24 June, 1918, and 1*s.* 6*d.*, on 8 July, 1918). These awards would affect the production of all classes of iron and steel, and the cost to the Government might be estimated at £6,000,000 to £7,000,000.

The cost of the whole system—rebates, subsidies and allowances, excluding the Sydvarangar arrangement—was estimated at the formidable total of £47,603,800 a year, made up as follows :—

	£	£
Imports—		
Hematite freight and insurance	24,651,900	
American basic pig iron	1,560,000	
Contribution to carrier lines	100,000	
	———	26,311,900
Home Production—		
Hematite subsidies, etc...	5,541,900	
Basic iron	3,000,000	
Foundry and forge iron..	1,750,000	
Subsidy of 15*s.* on steel..	5,000,000	
Coal Controller's awards of 24/6/18 and 8/7/18 ..	6,000,000	
	———	21,291,900
Total		£47,603,800

IX.—The Removal of Subsidies.[1]

(*a*) Fixing of Post War Prices for Iron and Steel.

As long as the war continued and the Government was practically the sole purchaser of goods made from iron and steel, the system of subsidies described above, which stabilised the cost of raw materials included in munitions, was maintained in order to avoid constant changes in the terms of a very large number of Government contracts, and also to prevent profits and wages increasing in a "spiral circle."

It was obvious, however, that the position would be completely altered as soon as hostilities ceased, when the Government would cease to be the chief purchaser of iron and steel goods. It had been anticipated for some time that a difficult position would arise at the end of the war owing to the existence of these subsidies and in September, 1918, an Inter-departmental Committee, under the chairmanship of Sir Clarendon Hyde, was appointed by the Minister of Munitions

[1] D.B./P/6.

to consider the question of their removal.[1] This committee had held several meetings before the Armistice was signed, and was generally of the opinion that the subsidies, which amounted roughly to about £2 10*s*. per ton on pig iron and £5 per ton on steel, should be removed almost immediately on the cessation of hostilities, and that prices for private trade should rise by the amount of the subsidies. The National Federation of Iron and Steel Manufacturers, however, were strongly opposed to the immediate abolition of subsidies, as they feared it would have disastrous effects on the trade.[2] On the one hand they feared that so large an increase in selling price would check demand at a critical moment and prevent the revival of export trade, especially of the tin-plate trade. But their chief argument against the immediate discontinuance of the subsidies was the fact that the consequent increase in price would necessitate a big increase in wages, which, in the iron and steel trades, were based upon the selling prices of pig iron and steel. This would involve further re-adjustments of price, and lead to prolonged negotiations and unsettlement in the trade, and probably increase unemployment at a time when the Army was being demobilised. Moreover, it was pointed out that any considerable increase of the wage rates in the iron and steel trades would affect wages throughout the whole country.

To a certain extent, the amounts paid in subsidies had already been included in determining the ascertained prices for the purpose of the sliding scales,[3] and to this extent the removal of subsidies and the throwing of the increased cost on to the selling price would not increase wages. The subsidies paid on pig iron, for example, had been included in calculating the ascertained pig iron prices, and similarly, the direct subsidy on steel making in the case of steel prices. But in the latter case, the amount of the subsidy paid on the pig iron used in making steel, which averaged about £2 10*s*. per ton of steel, had not been included. With the removal of the subsidies this additional £2 10*s*. per ton would have to go on to the sliding scale, and big increases in wages would automatically follow. The trade unions concerned were acquainted with the position, and had agreed to the view that indirect subsidies should not be included in arriving at the ascertained prices. But it was recognised that the position would be quite different when these indirect subsidies were added to the selling price and the trade expected a demand for increased wages in spite of the fact that during the war labour leaders, with full knowledge of the existence of these indirect subsidies, had made no claim in respect of them.

Sir Clarendon Hyde's committee, therefore, recommended (13 November) that subsidies should be removed in two stages. They thought the Minister would be well advised to accept this compromise in the interests of industrial peace, and to stabilise trade, so that orders might be booked, though they recognised that as long as subsidies

[1] The committee consisted of Sir Clarendon Hyde, Mr. Layton, Mr. Larke, Prof. Macdonald, Mr. Walmsley, Mr. Jones, Mr. Judd, with Mr. Drake as Secretary.

[2] Resolution on 12 November (HIST. REC./R/661/29).

[3] *See* above, p. 127.

were continued the private consumer would be getting a bonus. The committee recommended that the existing subsidies should continue unchanged until the end of January, 1919, maximum prices for home trade remaining at their existing level, and that on 1 February, 1919, the direct subsidies on steel amounting to about £2 10*s*. a ton should be removed and a new schedule of steel prices fixed from that date. This change would not have any effect on wages as the subsidy had already been discounted.

It was further proposed that all the remaining subsidies, including the pig iron subsidies, should be withdrawn on 1 May ; but in view of the difficulties that might arise owing to the operation of the sliding scales, if costs had not been reduced by that date, the makers asked to be allowed to bring the matter up again and represent to the Minister their reasons for continuing the subsidies or some part of them after that date. To illustrate the meaning of this arrangement, the effect would be to raise the home price of plates from £11 10*s*. a ton to £14 after 1 February, and unless a fall in production costs subsequently ensued, to £16 10*s*. after 1 May.

A schedule of maximum steel prices for home trade, to come into force on 1 February, 1919, when the steel subsidies were to be withdrawn, was issued on 2 December. The price of pig iron was to remain unchanged until 1 May.

The Minister approved these recommendations and obtained Treasury sanction for their adoption (16 November). It was estimated that the continuation of subsidies would involve an expenditure of £8,000,000 for the six months from November to April. The net loss would, however, be reduced by the amount of the subsidies recovered on exported iron and steel (estimated at £1,000,000), and by means of the excess profits duty if that was continued. Moreover, in so far as the output during the subsidised period was used for work in which the Government was financially interested, the subsidy did not represent loss.[1]

(*b*) Export Prices and Drawbacks.

The subject of export prices raised an important question of principle. The higher the price Great Britain obtained for her exports the better for her financial position, but there was a general feeling that prices to the Allies must be on a reasonable non-profiteering basis, in order to maintain the joint understandings on finance, food and shipping.[2]

It was agreed that these export prices should be fixed prices, not maximum prices only.[3] This principle was adopted in order to meet

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[1] D.B./P/6.

[2] Conference with National Federation of Iron and Steel Manufacturers, 20 November, 1918 (Hist. Rec./R/661/29).

[3] This was confirmed by the Treasury on 16 November. (43817/18 in DB/P/6).

the objection of America on the one hand, that it would be possible for British merchants to export cheap subsidised steel if the prices fixed had been merely maximum prices with freedom for the exporters to charge as low a price as they like ; and the general objection of the other Allies, on the other hand, that differential treatment would be accorded to different countries and in different markets if the prices were minimum prices with freedom for exporters to fix any prices they could get above the scheduled figures.

Export prices were therefore published for pig iron, crude steel, and certain classes of semi-manufactured steel, which were based upon the maximum home prices plus the amount of the government subsidy.[1] The addition in respect of subsidies was refunded to the Government, and arrangements were made with the Board of Customs and Excise to collect drawbacks equivalent to the difference between the export prices and the maximum home prices.[2] When the exporter was also the manufacturer the drawback was paid by deduction from the subsidies due to him by the Ministry. When the exporter was not the manufacturer he was required to pay the drawback when he presented his export licence to the officials of the Board of Customs and Excise.

In order that Labour might be made fully conversant with the proposed policy, a meeting was held at the Ministry of Munitions (29 November), with Sir Thomas Munro in the chair, at which representatives of the trade unions and of the employers' associations were present. The extent to which the existence of the government subsidies had been taken into account in arriving at the ascertained prices for the purposes of the sliding scales was explained as well as the reasons for the proposed increase in prices on 1 February and on 1 May, respectively. It was explained why no advance in wages would follow the removal of subsidies on 1 February, although an advance in those wages which were based on the selling price of steel would follow the proposed removal of the subsidies on pig iron on 1 May, unless in the meanwhile, the cost of production had been reduced to such an extent that no increase in the price of steel need take place, notwithstanding the removal of the subsidies.

No attempt was made to fix prices for manufactured goods (including machinery) either for home trade or for export. It was originally hoped that it would be possible to collect the export drawback on manufactured goods (28 November), but the machinery devised for the collection of the drawback for other classes of iron and steel depended upon the existence of (*a*) export licences and (*b*) fixed prices. As export licences were in operation for only a limited number of manufactured goods, and there were no fixed prices in existence for

[1] Sec/Gen/348.

[2] The Board of Trade, the Board of Customs and Excise, the War Trade Department, the Foreign Office and the Treasury were represented at a meeting held on 18 November to discuss the machinery to be set up for collecting the drawback.

manufactured goods, it was felt that even if the machinery could be set up (which was doubtful), the amount of money involved was not sufficient to warrant the labour and expense, and the setback to industry generally that the collection of the drawback would involve in this case.

Special agreements (12 and 13 December, 1918), were entered into with the galvanized sheet and tinplate trades—both large exporting industries—under which the manufacturers concerned were to repay to the Government a fixed sum per ton of steel delivered to tinplate and galvanising works equal to the total subsidies paid by the Government on the iron or steel in question, whether used in products sold at home or abroad. In consideration of this refund the Government agreed to waive all right of controlling prices for export to neutral markets, and to private buyers in Allied and colonial markets; provided that the prices for home trade and for government orders from colonial and Allied countries were approved by the Ministry of Munitions.[1] This last provision left the Government free to make bargains with Allied Governments as occasion arose.

(*c*) The Distribution of Stocks.

The Ministry recognised that the scheme for removing subsidies by two stages might open the door to two evils, namely an unfair distribution among consumers during the period of subsidies on the one hand, and on the other hand the undue accumulation of stocks by those who had the means of storing material. In order to deal with the first difficulty, a Standing Committee of Iron and Steel Manufacturers, consisting of one representative from each district, was appointed to advise the Ministry of Munitions on all questions relating to iron and steel. Local committees were also appointed consisting of the Area Steel Committees, to which representatives of the iron masters and of the consuming industries were added. These committees were to assist locally in the transition from war to peace conditions, and to deal, in the first place, with any complaints of unequal distribution of subsidised iron and steel. The Central Steel Committee was constituted the final court of appeal in such cases.

In order to protect the public purse and to discourage the piling up of stocks of steel during the period of subsidies to be sold later at higher prices, an order was issued on 7 January, 1919, to the effect that no person might increase his stock of steel[2] by more than 100 tons beyond the basis level of his stock held on 31 October, 1915, or 31 October, 1918 (whichever was the greater), without obtaining a permit from the Ministry of Munitions. These permits were to be granted freely to all applicants on condition that a certain sum per ton, equivalent to the amount of the government subsidy, was paid by the stockholder to the Government on all excess stocks. Persons holding less than 100 tons in stock were not required to apply for a permit.

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[1] C.R.V./Gen./1352.

[2] Or iron, or the two together.

One of the effects of this policy of gradually increasing prices was to stimulate the placing of orders at the earliest possible moment, and in January, 1919, the iron and steel trade, with the exception of a few firms engaged in the manufacture of special steels, was busily occupied on peace orders and expected to be full up with work for some time to come.

(*d*) Suspension of Control of Cumberland Iron Ore Mines.

Under the agreement with the Cumberland mine owners,[1] the period of control was to continue until "the expiration of a period of four months after the conclusion of peace between the United Kingdom and Germany." Soon after the Armistice, however, Mr. Webster Jenkinson and Sir Gilbert Garnsey suggested that since the working of the mines involved a monthly loss of £58,000, the mine owners should be induced to resume control before the period fixed under the agreement.[2] It was to the advantage of the Ministry to retain control up to 30 April 1919, when subsidies ceased, as otherwise a subsidy would have to be given to the mine owners, the price of their product being fixed. After 30 April, when fixed prices would be abandoned, it would be to the interest of the mine owners to recover their property.

An agreement was therefore drawn up under which control was to cease as at 30 April, the Ministry paying for the four months, May to August the monthly average total net loss on the scale of losses during the six months ending 30 September, 1918, adding thereto any increase in wages between that date and 30 April, 1919. The Ministry therefore escaped the obligation to pay increasing losses due to higher cost of production and decreasing output, while the period of its liability to loss, which would otherwise have extended to four months after the conclusion of peace, was limited. Though showing a net loss it must be remembered that the working of these mines provided some 1,048,022 tons of vitally necessary ore at a saving of £4,884,220 over the cost of the same quantity of Spanish ore, the landed cost of the latter being 126*s*. 3*d*. per ton, while the cost of production of the former averaged 33*s*. 0½*d*. per ton.

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[1] See above, p. 110.
[2] F.A.6/Gen/5, 20 February, 1919.

CHAPTER VII.

STEEL INSPECTION AND CHANGES IN MANUFACTURING METHODS.

No accounts of iron and steel supply would be complete without some reference to the inspection and manufacturing problems which occupied the Department's attention. One of the chief difficulties of the Ministry with regard to steel was to reconcile the divergent and often conflicting interests of the Services, the steel makers, and the shell makers. The Navy and Army required an enormous increase in the output of steel, especially shell steel, but demanded a high standard of quality that could only be produced by experienced steel makers and maintained by very strict inspection involving the application of rigorous chemical and mechanical tests. As will be seen below these conflicting interests were ultimately reconciled, not without some difficulty and opposition, by some reduction in the standard of quality, accompanied by a temporary relaxation of methods of inspection, which was entailed by the shortage of trained staff and was not found to be entirely satisfactory. These concessions led to a great increase in output, and the slightly increased risk of failure in the field had to be accepted as the price of increased supply, much of which came from firms in the United Kingdom, Canada and the United States, who had no previous experience in the manufacture of a specialised product like shell steel. Meanwhile research and experiment by the Minister's technical advisers improved the actual processes of manufacture with a view to obtaining sounder steel, while normalising and oil and water treatment were resorted to in special cases to improve its quality.

Similar factors operated in the case of special tool steels, gun steels and steel alloys, and research and manufacturing experiments were carried on in the laboratories controlled by the Ministry and Admiralty, at the works of chemical analysts and of manufacturing firms.

Special efforts had to be made to induce the makers of commercial steel to take up the manufacture of shell steel. The Ministry of Munitions availed itself to a great extent of the services of the technical experts employed by the armament firms to teach the new makers, who were used neither to the class of steel required nor to working to specifications of such a rigorous nature as required by the War Office. A very close system of inspection was necessary, and at first a considerable quantity was rejected. This initial difficulty was overcome, and not only was the shell steel produced, but a great improvement resulted throughout the country in the quality of steel manufactured

for all purposes. In South Wales also, where many of the French shell steel contracts were placed, the members of the French Technical Commission were of great service to the firms who had undertaken to manufacture to an even more difficult specification than that of the War Office.[1]

I. Steel Specifications.

The severity of the existing War Office specification for shell steel was a serious limitation on supply, and at the instigation of the Ministry of Munitions important investigations were made as to the effects of the different constituents of steel, with a view to allowing a greater percentage of sulphur and phosphorus in shell steel. By June, 1915, the limit had already been relaxed to ·05 per cent. for land service shell and to ·04 for naval shell, but in August, 1915, Dr. J. E. Stead submitted a report to the Minister urging that the specification was unnecessarily stringent, a view also supported by the Steel Makers' Committee.[2] He continued to make investigations, making an analysis of German shell steel, which proved that the enemy allowed a much higher percentage of sulphur and phosphorus, and as a result the Ordnance Board appointed a committee, consisting of Dr. Harbord, Sir A. Kennedy, the Chief Inspector, Woolwich, and the Superintendent of Research, to draw up a scheme with a view to determining the maximum of sulphur and phosphorus which might be permitted. A series of tests were carried out, including mechanical and other tests as well as firing trials, which proved that steel up to ·08 per cent. of sulphur and phosphorus was safe for shell steel.

On 14 October, 1915, the Army Council sanctioned the use of steel containing sulphur and phosphorus up to a maximum of ·06 per cent. of each for land service shell of 5-in. and below,[3] the concession being extended to all calibres of H.E. shell on 11 December.[4]

After a series of further tests and investigations the specification was again relaxed, the percentage being raised to ·07 in April, 1916, and to ·08 in February, 1917, for shell of 6-in. and below.[5] The effect of this in widening the area of supply was very great. The specification was relaxed in another direction by sanctioning the use of Bessemer as well as open-hearth acid steel, the concession however being limited to steel made by certain specified firms.[6] The Admiralty, however, were not prepared to accept these modifications, and the specification for naval shell steel remained very high, only open-hearth acid steel being allowed and a 40 per cent. discard from the

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[1] Sir L. Llewelyn's Papers, 19, 20A.

[2] For a more detailed account see Vol. X., Part III., Chap. V.; D.G.M.D/S/168.

[3] D.G.M.D/S/228.

[4] D.G.M.D/S/168; C.R.2369.

[5] D.G.M.D/S/168, 245. In July, 1917, the percentage of sulphur and phosphorus allowed in gun steel was raised from ·035 to ·045 as the best quality pig iron was very difficult to obtain. (Printed) *Weekly Report*, No. 101, I. (21.7.17).

[6] D.G.M.D/S/12.

ingot being insisted on. As a result the steel could only be made by a few firms, and the Ministry urged, on Dr. Harbord's advice,[1] that the Admiralty should accept ·06 instead of ·04 of sulphur and phosphorus, even if they were unable to accept the higher percentage sanctioned for land service.[2] At the beginning of 1918, the percentage of sulphur and phosphorus in steel used for railway locomotives and wagon wheels and axles was raised,[3] and the use of basic instead of acid steel for railway crossings and points was advocated.[4]

The attempt to get the specification for British and French shell steel unified, in order to facilitate purchase in the United States, was not successful.[5]

II. The Inspection of Iron and Steel.

(*a*) Inspection by the Admiralty, 1909–17.

Prior to the formation of a Naval Inspection Department in February, 1909, the inspection of iron and steel for both naval and land services was under the control of the Chief Inspector, Woolwich. The headquarters of steel inspection were at Sheffield, where the work was carried out by an Inspector of Steel assisted by a staff of naval and military officers. His duties included the inspection of raw materials, principally steel, and the superintendence of gun casting and shell manufacture by the armament firms.

Early in 1909 the whole system of inspection was changed; a Naval Inspection Department was established and a Chief Inspector of Naval Ordnance was appointed.[6] The Inspector of Steel with his staff was transferred from the control of the Chief Inspector, Woolwich, and placed under the newly appointed Chief Inspector of Naval Ordnance,[7] the military personnel being gradually eliminated from the staff, which at the beginning of 1912 consisted entirely of naval officers. The Inspector of Steel continued to have his headquarters in Sheffield, and became responsible for technical inspection and personnel in the steel-producing districts of the Midlands, North of England, and Scotland. Subsequently, owing to the increase of work during the war, an Assistant Inspector of Steel, with headquarters at Newcastle, was appointed to take charge of inspection in Scotland, the Newcastle district, and Middlesbrough, reporting direct to the Chief Inspector of Naval Ordnance.

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[1] C.I.S.P/Gen/411
[2] C.I.S.P/Gen/398.
[3] A.M.2/C/57c; C.I.S.P/Gen/65.
[4] M.C. 60.
[5] C.I.S.P/Gen/76.
[6] Mr. Collinson's Papers, No. 13 (these unregistered papers are now filed in the Archives Registry).
[7] *Ibid.*

The steel works in South Wales were not included in the sphere of either of these officials, and when, soon after the outbreak of war, steel for munitions was ordered from South Wales, great difficulty arose over the question of inspection in these works. The Naval Inspector of Steel had no staff in South Wales, it was impossible for him to spare trained inspectors, yet it was imperative that a high standard of inspection should be maintained. Ultimately, the Board of Trade relieved the situation by becoming responsible for steel inspection in South Wales, and by arranging that the analytical tests should be carried out by a firm of analytical chemists at Cardiff.

The work of chemical analysis in other areas was at first performed under the superintendence of the Chief Analyst on the staff of the Inspector of Steel at the Admiralty Inspection Offices in Sheffield. With the increasing pressure due to the war, analytical work was also carried out at Sheffield University, at Workington, Manchester, Middlesbrough, Glasgow and Birmingham. The breaking of test pieces of steel and other mechanical tests were performed, under the supervision of Admiralty inspectors, at the national factories and the works of the armament firms as well as in the Admiralty Inspection Offices.[1] The Admiralty dealt with the inspection of steel up to the point when the forging had passed the chemical and mechanical tests, but the actual inspection of shell in all its stages was carried out by the Director of Inspection of Munitions Areas or, in the case of guns and trench howitzers, by the Director of Inspection of Guns and the Director of Inspection of Trench Warfare respectively.

In the summer of 1917 the Admiralty decided that owing to the pressure of work it was unable to continue the inspection of land service steel any longer.[2] The work had grown to such proportions that the value of the steel for land service shell dealt with amounted to some £500,000 per week, the steel being produced at 24 steel works in five districts. It appeared that increased efficiency and economy would be gained by centralising the inspection of land service steel and localising responsibility with officers who had had practical experience in the use of the guns and munitions in the field.

(*b*) INSPECTION BY THE MINISTRY, 1917–18.

Negotiations for the proposed transfer continued during the summer of 1917, and in October, 1917, after a joint departmental conference between the Admiralty and the Ministry of Munitions, it was decided to transfer the inspection of land service steel to the Ministry of Munitions. A new directorate for the inspection of land service steel was established, the Director (Mr. N. P. P. Sandberg)[3] being responsible

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[1] Mr. Collinson's Papers, No. 13.

[2] *Ibid.*

[3] Office Memoranda (Inspection Department), Nos. 145, 176 (Mr. Collinson's Papers, No. 13).

to the Inspector of Munitions for the inspection of all steel ordered by the Ministry, up to the stage when the forging had passed the chemical and mechanical tests.

His duties as defined in Inspection Department Office Memorandum No. 176 of 8 November, 1917, were to supervise the mechanical and chemical testing of steel for land service use at practically all the steel works in the country. In works where test pieces for both services were broken, as for example, Elswick and Openshaw, inspectors from either service were to supervise the preparing and breaking of their own test pieces. The Director of the Inspection of Steel (Land Service), was also to decide whether samples submitted to him conformed to the specification or came within permissible tolerances, and to keep records of forgings and, for a certain time, the test pieces of the forgings dealt with by him. He was to forward all samples which did not conform with the specification to the Directors inspecting the store for which the steel was to be used. He was also to visit the various steel works in person periodically with a view to standardising inspection and establishing and maintaining good relations between the steel manufacturers and the Inspection Department.[1]

After the steel had passed the chemical and mechanical tests, the responsibility of the Director of Inspection of Steel (Land Service) ceased; the inspection of shell in all its stages being carried out by the Director of Inspection of Munitions Areas, while the Directors of the Inspection of Guns and Trench Warfare continued to inspect gun steel during the building up and proof of guns and trench howitzers and to draw up specifications for gun, howitzer and trench howitzer steel, and dealt with technical questions relating to it as they had done hitherto.

The transference of steel inspection from the naval Inspector of Steel, to the Director of Inspection of Steel (Land Service), could only be gradual owing to the difficulties involved in equipping further laboratories and in obtaining an efficient technical staff. As the Admiralty laboratories in Sheffield were barely sufficient to meet the needs of the Navy, the Ministry of Munitions decided to equip a new testhouse and laboratory in Sheffield to be used exclusively for land service steel. The Admiralty agreed to transfer the existing chemical laboratories at Workington and Manchester to the Ministry. Where the analysis was carried on for both services under Admiralty control in a University, as for instance at Glasgow and Birmingham, the Admiralty was to continue the supervision. The question of securing staff with adequate technical qualifications and experience was even more important than the provision of suitable accommodation, and the Admiralty sanctioned the transfer of a proportion of their staff, already engaged on land service steel, to the Ministry of Munitions, while their Chief Analyst in Sheffield was prepared to advise on the plant and equipment of the new laboratories.

[1] (Printed) *Weekly Report*, No. 117, XIII (10/11/17).

By the spring of 1918, the Director of Inspection of Steel (Land Service) had his department fully organised. In April, 1918, he reported that the plant for the preparation of test pieces at Templeborough, Sheffield, was able to deal with practically all land service tests; the inspection of gun steel and forgings had been taken over in the Leeds, Manchester and Birmingham areas and would be taken over in Sheffield within a few weeks. Owing to labour difficulties, the new testhouse and laboratory for the Ministry in Sheffield was not yet complete, but the officers who were to deal with the work were installed.[1] The new department was working smoothly, and in spite of increasing difficulties in production, a high standard was being maintained.

(*c*). METHODS OF INSPECTION.

The difficulties with which the Government were confronted in securing a system of inspection which was sufficiently elastic to admit of a greatly increased output, yet, at the same time, sufficiently stringent to prevent defective steel from passing out of the foundries, were very great. Sufficient supplies could only be secured by some relaxation of pre-war standards and by giving wider discretionary powers to the inspection officials. Officials from the Inspection Department were responsible for seeing that steel was manufactured according to specification; for checking the discard and fracture; for taking samples for chemical analysis and for watching the rolling and transferring inspection marks where necessary. Samples and test pieces were kept under the control of the inspection officials, and great importance was attached to this practice. "The general principle is always adhered to,"[2] said the Inspector of Shell at Woolwich, "that samples should be selected by an assistant inspector, should remain under our control or observation from the time of selection, and should govern a definite quantity of materials or number of articles, the whole of which must be available for selection when it is made, and marked or bonded to identify it or them with the sample. These principles apply to all kinds of samples, whether taken for analysis, test, selection, proof, or other purpose." While standards were not relaxed, supply was facilitated by giving greater latitude to individual inspectors in the acceptance of steel that did not conform to pre-war requirements. For example, in taking the tensile tests for H.E. shell steel, inspectors were given discretion to accept steel which showed a variation of between one and two tons from the breaking point laid down in the specification and up to a maximum of one per cent on the extension. No latitude, however, was permissible in the yield.[3]

In addition to the discretionary powers allowed to the inspectors, certain modifications were made in the methods of inspection for shell steel. The most important changes were that a discard of

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[1] Mr. Collinson's Papers, No. 13; D.G.I.M. 505.
[2] Mr. Collinson's Papers, No. 22, p. 18.
[3] *Ibid.*, p. 13.

20 per cent, taken after rolling, was substituted for the 40 per cent, hitherto taken cold from the ingot, before rolling; again, for a time, the practice of fracturing every billet was relaxed, results being taken upon a percentage basis, but this latter concession was not found to work well, as steel from the same cast varied greatly, and piping and other defects were liable to pass undetected,. The former system of fracturing every bar was therefore reintroduced in 1916. As has been seen, the specification for shell steel was modified to allow a higher percentage of sulphur and phosphorus,[1] and the practice of bottom pouring, which had hitherto been forbidden, was allowed. Another war concession was to allow makers of steel for 6-inch shell and under to take steel for analysis (which before the war had always been taken from the centre of the top of the ingot, where segregation was greatest) from halfway between the centre and the outside of the ingot.

The difficulties of inspection were greatly increased by the fact that steel for naval and military use was no longer manufactured by a few approved firms. The practice of forging sample billets and purchasing steel from the evidence of these samples, became common, but it was condemned by many inspection officials as unsound in principle. Another point at issue between the steel makers and the Inspection Department was the question of keeping steel from the same cast as much together as possible, so that, in case of any defects arising, the steel could be traced more easily. The principle of the Inspection Department was to test every cast of steel after forging into shell. Early in the war one steel-making firm, having difficulties in steel supply and works organisation, succeeded in getting permission to submit by day's work instead of by casts, as they could not get the casts together. They maintained that the effects of cast variations were swamped by those of forging; experience with the method, however, did not support this, and in 1917, it was being dropped, though still officially permitted by specification.[2]

(*d*). Steel Inspection Overseas.

The scarcity of steel in Great Britain made it essential to obtain supplementary supplies, and early in the war, contracts were placed with the Bethlehem Steel Company and other great steel corporations in the United States. As American steel manufacturers could not be induced to accept contracts on the conditions laid down in the British home specification for H.E. shell steel, the specification had to be relaxed to induce them to undertake orders.

The task of inspection in the United States was one of great difficulty, as the manufacturers did not appreciate the high standard

[1] See above, p 139.
[2] Mr. Collinson's Papers, No. 22, p. 19.

required, and rigid re-inspection was necessary when the forgings and shells reached England.[1] The need for a more adequate staff of trained inspectors became pressing and the unsatisfactory nature of some of the steel shipped to England in the winter of 1915-16 brought matters to a crisis.

The system of inspection was re-organised by General Minchin (April to September, 1916), who was followed by Colonel Kenyon. The latter held a detailed investigation into the methods of inspection then in force. Two travelling inspectors were appointed to standardise steel inspection and to re-examine a percentage of the inspected work, making their reports direct to headquarters. Hitherto the selection of tests and inspection of the breaking of samples had been largely left to examiners and the tests had been taken by the firm. Colonel Kenyon decided, upon the advice of Mr. Collinson, that in future the fracture of all test pieces should be witnessed by an inspector, who would take his own records of the results.

In the summer of 1917, pressure was brought to bear upon steel manufacturers in the United States to adopt improved methods in casting the ingot. At the same time Mr. Collinson's recommendations for testing steel were carried into effect. The Inspection Department took over 5 per cent. of the tests, and measurements made by the firms were carried out in the presence of an assistant inspector. The value of these changes was soon apparent in the improved quality of the steel and the more satisfactory level of output in the final stages of the war.

The inspection of steel in Canada was a branch of the Inspection Department as a whole, and the Inspector of Steel was responsible to the Chief Inspector in Canada.[2] Only comparatively small orders for steel were placed by the Shell Committee, but with the greatly increased output under the Imperial Munitions Board, a more comprehensive system of inspection became necessary. Canada was divided into six districts for general inspection purposes, and in three of these—Eastern Canada, Montreal and Western Ontario—a separate staff was appointed to undertake the inspection of steel. The difficulties arising from shortage of staff, and the great distances between the centres of steel production, which hampered the work of inspection in the United States, were felt with equal force in Canada, and in addition, Canadian manufacturers had had much less experience in the production of steel upon a large scale than was the case in the States. Inspection officials found great difficulty in impressing upon the manufacturers the necessity for a high standard of production, and in many cases no amount of pressure could induce them to accept contracts for steel made in accordance to British specifications.

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[1] For an account of the administration of inspection in the United States, see Vol. II, Part III, Chap. VII.

[2] HIST. REC:/R/1142/41.

In February, 1916, the Government tried to induce Canadian manufacturers to determine the yield point for H.E. steel by the scribed line test instead of by the drop-beam method which they had hitherto adopted, but so great was the opposition that the inspectors were told not to enforce the new specification until they received further orders.[1] The great increase in the output of steel in Canada in the summer of 1916 put a greater strain upon the Inspection Department than it was able to meet. Many of the examiners were insufficiently trained and were in too inferior a position to impress on the manufacturers the high standard of output required. The examiners themselves, in some cases, lacked knowledge of the requisite standards, yet owing to shortage of staff too much was left to their discretion and the testing of steel, which should have been done in the presence of a chief examiner, was often supervised by an assistant inspector.

When, in the summer of 1916, great anxiety was caused by premature explosion of shells which it was thought might be due to defective steel supplied by Canada, steps were taken to reorganise the whole system of inspection and place it upon a more satisfactory basis. Considerable trouble arose from the fact that the yield point for steel had been wrongly determined by the Canadian authorities, and instead of a half per cent. extension, one per cent. had been permitted, with the result that a large quantity of shell delivered was under the 19-ton yield. After numerous trials it was decided that a yield of 17 tons was the minimum which could be allowed, and all the shell affected had to be re-inspected and Brinell tested, all below a Brinell number corresponding to a 17½-ton yield being rejected.

The wide discrepancy which had been revealed between the standard of steel testing in Great Britain and Canada was one of the causes which led to the Canadian Inspection Department being brought under the administrative control of the Ministry of Munitions, as had already been done in the United States.[2]

The standard of steel production in Canada improved in 1917 and 1918, although the steel companies were not willing in all cases to adopt the improvements for shell steel advised from England. The difficulties of steel making, on the other hand, were continually increasing owing to labour and transport conditions and lack of satisfactory raw materials, especially low phosphorus-hematite for the acid process. In 1918, concessions were made allowing a higher percentage of phosphorus and sulphur, which eased the situation, and upon further representations from Colonel Carnegie the carbon specification for 19-ton H.E. steel made by the basic open-hearth process was raised to 0·60 per cent. A favourable report was made by Mr. N. P. Sandberg after a thorough investigation of steel production in Canada in January, 1918.

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[1] Vol. X., Part V., Chap. IX.
[2] See Vol. II., Part IV., Chap. II., for a further account of this.

III. Technical Research and New Processes.

War conditions not only demanded an increased output but also an economy in materials, and continual efforts were made to find satisfactory substitutes for imported raw materials or new methods by which the output of steel could be maintained. Thus the erection of basic furnaces, already so successfully and largely used in the United States industry, enabled the British manufacturer to rely to a much larger extent on home ores. The older Bessemer process for both acid and basic steel was, wherever possible, replaced by open-hearth furnaces, in which a smaller proportion of pig iron was needed to produce the same quantity of steel and a larger proportion of steel scrap could be used. Such a change made in a furnace at one large steel works was estimated to save 62,400 tons of pig iron a year.[1]

Experiments were also carried out to discover a satisfactory British substitute for the Swedish bar iron used in the manufacture of tool steel. Certain Sheffield firms experimented, at the instance of Dr. Harbord, with two kinds of material, " Armco " iron, an exceptionally pure iron made from common phosphoric pig iron, and with a special dead soft basic steel, with which they made sets of tool-steel bars. These were tested by Professor W. Ripper at Sheffield University laboratory in comparison with tools made from Swedish iron and the tests were found to be entirely satisfactory.[2] A considerable amount of tool steel was made in consequence from British materials, but the import of Swedish bar iron could not be entirely dispensed with during the war, without diminishing the output of other kinds of iron in Great Britain.[3]

The requirements of the Ministry of Munitions also had a very considerable effect on the manufacture of foundry iron, which had been one of the most conservative branches of the steel and iron industry. In the spring of 1917, the tank programme resulted in a great deficiency in malleable foundry iron, but the demand for increased production was taken up with considerable vigour and initiative. A Committee of Malleable Iron Founders was instituted in April, 1917, at the instigation of the Director of Forgings and Castings, but the meetings of the committee revealed, amongst many of the ironmasters, a great lack of knowledge of the results to be arrived at by research or even of the fundamental scientific principles underlying their foundry practice. The first questions which occupied the Ministry were the standardisation of malleable hematite pig iron and the extent to which dilution with special iron was possible. They were also concerned with the methods by which foundry practice could be improved and reorganised. Inquiry showed that a consider-

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[1] D.S.P/Gen/20, C.I.S.P/Gen/500.

[2] Tests of other substitutes made from steel turnings, and from Cleveland iron in an electric furnace, were made at Manchester and by various steel makers (C.I.S.P/Gen/400 ; C.I.S.P/Gen/449).

[3] C.I.S.P/Gen/463 ; C.I.S.P/Gen/449. *Iron and Steel Industry*, 1914–18, p. 16 ; HIST. REC./R/1810/47.

able amount of scientific work on malleable castings on the metallurgical side had already been accomplished at Sheffield University, but had been completely ignored by some of the malleable iron founders, who clung to old-established "secret processes." The Ministry, therefore, in July, 1917, circulated a pamphlet by Dr. W. H. Hatfield on the conditions in the malleable casting industry, urging a greater interest in the scientific side and the abandonment of trade secrets, which were fatal to all progress. The pamphlet appears to have aroused great interest; a large proportion of the firms to whom it was sent wrote to the Ministry mentioning their particular difficulties. One firm immediately established a laboratory at their works, offering to send any results attained there to the Ministry of Munitions.[1]

Research was furthered directly by the Ministry taking over a small foundry at Brentford, where experiments on the standardisation of hematite pig iron were carried out. Assistance in research was given in many ways by the Iron and Steel Institute, which also set up in 1917, a Research Association for the co-ordination and further promotion of the study of refractory materials.[2] During the war, the manufacture of refractory materials was largely increased, and in two cases—magnesite bricks and coke oven bricks—the British manufacturer, with the assistance of the Ministry, produced articles which previously had been entirely imported from abroad.

Among the specialised investigations undertaken by the Steel Department were the experiments to find a steel which would withstand considerable pressure at a temperature of about 11,000° or 12,000° F., in the course of which trials with nickel, high chrome and tungsten steels were conducted,[3] tests of a special alloy tool steel at the request of the Russian Commission[4] tests of a method of casing mild steel with white iron for armour plate purposes,[5] and tests to obtain a standard analysis for tungsten powder in order to eliminate some of the waste that was taking place in the manufacture of high speed steel,[6] were carried out and a large number of new processes and ideas put forward by manufacturers and inventors were investigated.[7] These examples are chosen at random to illustrate the general character of this research work. A feature of it is the help afforded by the armament firms in producing small quantities of the new special steels or irons, the actual testing and analysis of the product being carried out by the firms' analysts, and checked in University laboratories and by the Ministry's technical advisers or by consulting metallurgists employed by them. If the experiments were successful, manufacture on a commercial scale was begun, usually with some financial help from the Ministry.[8]

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[1] A.C. 514.
[2] A.C. 514; M.C. 105.
[3] C.I.S.P/Gen/398. (March, 1918.)
[4] C.I.S.P/Gen/374. (March to May, 1917.)
[5] C.I.S.P/Gen/372. (July, 1917.)
[6] C.I.S.P/Gen/346, 347. (May, 1917–November, 1918.)
[7] C.I.S.P/Gen/64; M.C. 105; PM/Gen/948.
[8] C.I.S.P/Gen/449.

In addition the metallurgical branch of the Research Department, Woolwich Arsenal, which was transferred to the Ministry of Munitions in November, 1915, carried out various researches into the general properties of metals and alloys, methods of testing, examination of failures. They undertook work to assist contractors, and gave advice on the relaxation and alteration of steel specifications and methods of manufacture.[1] Thus in June, 1916, the Superintendent of Research advocated that the existing specification for steel for high explosive shell should be modified and the carbon and silicon content increased with a view to securing harder steel. Hard steel, however, was unpopular with the shell manufacturer owing to the difficulty of machining it,[2] though a certain amount of it had to be made for shrapnel shell, usually by the acid Bessemer process.[3] The Superintendent of Research frequently advised manufacturers as to defects in the process of manufacture which resulted in the production of defective steel, as for instance, when flaws were caused by heating the ingot too quickly before rolling.[4]

IV. Improvements in Plant.

The increased production of iron and steel for munitions purposes resulted in great improvements in plant. It is interesting to notice that the great extension of output was not secured, as in other munition industries, largely by the erection of national factories, but by extensions to the works of existing makers aided by grants from the Government. Financial assistance could only be obtained from the Ministry on the understanding that the new plant was the most modern obtainable. The extensions sanctioned after the formation of the Iron and Steel Department had not only to be suited to the immediate purpose, *i.e.*, the production of war material, but were planned for conversion for peace production. All estimates and plans were submitted for approval to the Ministry and existing works were continually inspected before any scheme was adopted.[5] The information thus obtained showed that, even at the large works the layout was unsatisfactory and had resulted from haphazard building.[6] For the new schemes, transport facilities and the supply of raw materials were taken into consideration and large works were to be made self-contained and self-supporting.

Some of the proposals put forward by Sir John Hunter, in 1916, illustrate the principles on which the Department endeavoured to work. In the case of a firm which had previously built seven new furnaces for shell steel, the Ministry proposed that three more open-hearth furnaces should be installed, together with plate mills, with

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[1] Estab. Cent. 1/281. For an example of a joint investigation by Superintendent of Research, D.I.M.A. and D.I.G.A.T. at shell factories and steel works, *see* C.I.S.P/Gen/411.

[2] Ordnance Committee Minutes, 5197 (26 June, 1916). See also Vol. X., Part III., Chap. V., (Printed) *Weekly Report*, No. 105, XIII, (18.8.17).

[3] C.I.S.P/Gen/500.

[4] C.I.S.P/Gen/411.

[5] HIST. REC./R/1810/45.

[6] Sir L. Llewelyn's Papers, 325.

sufficient capacity to roll steel for all 10 furnaces. Another firm had had extensions sanctioned the previous year for shell castings at the rate of 6,000 tons a week ; these were to be completed by the erection of cogging and finishing mills for plates and sections so as to make the plant of use for post-war manufacture. The scheme proposed for a third firm involved increasing the production of pig-iron by adding blast furnaces, in order to bring up the output of iron and steel to the capacity of the existing rolling mills.[1] By these and similar schemes the producing power of the country was not only largely increased but the works permanently benefitted by improved methods and working economies.

The larger schemes involving the erection of entirely new units, consisting of coke ovens, blast furnaces, steel works and rolling mills, equipped in the most up-to-date way, could not be accomplished under war conditions, but the plans were drawn and considered by the experts at the Ministry for future service.[2] Works were also erected for the manufacture of ferro-tungsten and tungsten powder, which were required for one of the most important steel alloys, and had largely come from Germany before the war.

There was a considerable development in the use of electric furnaces, which could utilise light steel scrap without loss of iron due to oxidation, for the manufacture of high grade steel and for the production of castings of special quality. They afforded a means of rapidly converting highly phosphoric ores into good quality steel, producing as a by-product basic or phosphoric slag, which was a valuable fertiliser.

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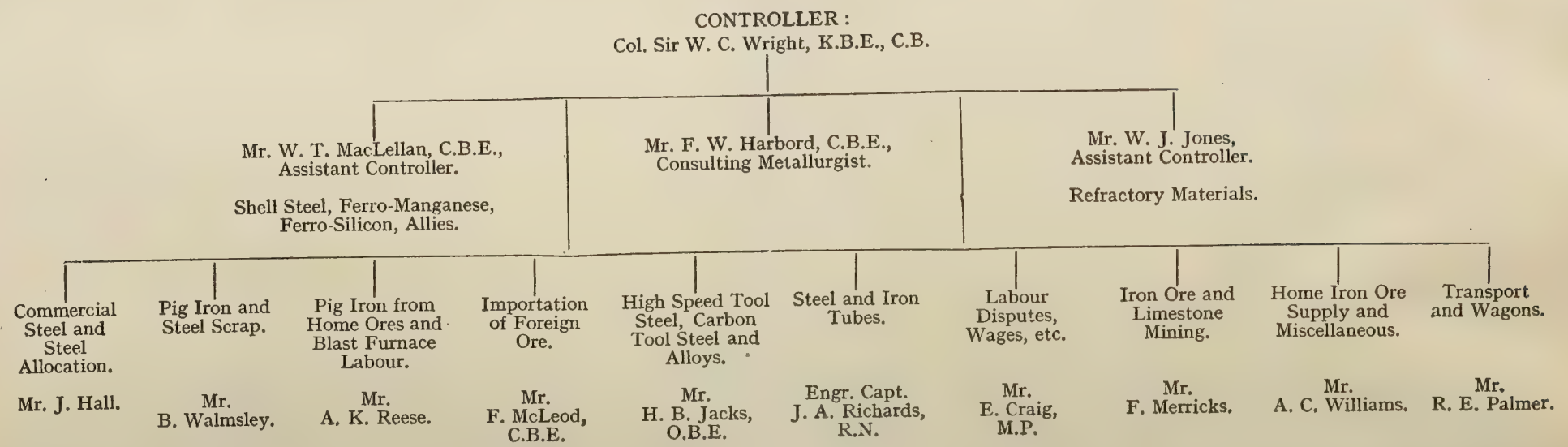
[1] D.S.P/Gen/20.
[2] *Ibid.*

APPENDICES.

APPENDIX I.

(CHAPTER I, p. 5.)

Organisation of the Iron and Steel Production Department, August, 1918.



APPENDIX II.

(CHAPTER I, p. 15.)

Interim Report by Lord Curzon, Chairman of the Committee on the Increased Mercantile Ship-building Programme, 3 August, 1917.

The Committee was appointed by a decision of the War Cabinet (W.C. 180, Minute 19), to examine the steps that should be taken as regards the supply both of steel and labour, and carry into effect the programme of increased merchant ship-building, up to a total of 3,100,000 tons per annum, that was submitted to the War Cabinet by Sir E. Geddes, and approved in principle by them.

The Committee has held several sittings at which the representatives of the various Departments concerned attended and stated their case. In order that the War Cabinet may be seized of the situation, and may give the requisite authority for carrying out their instructions, on points where there is not complete agreement between the Departments, I have decided to submit this interim Report to the War Cabinet, whose early decision is solicited.

I. MATERIAL.

The present output of finished steel, exclusive of Shell Discard Quality, is:—

Per week, about 140,140 tons. The main purposes for which this supply is used are :—

	Tons per week.
For making Shell and Shell Parts for British	32,455
,, ,, ,, ,, Allies	10,955
War Office, including Railways, "Tanks," Trench Warfare, I.W.T. Mechanical Transport and General Purposes	12,908
Admiralty, including Auxiliary Craft	14,032
Mercantile Marine	14,357
Construction Work	4,035
Guns	3,625
Aircraft	1,016
Railway Maintenance	2,767
Wheels and Tyres	962
Locomotives	634
Export (other than Shell Steel)	8,130

The present supply of steel to merchant ship-building is sufficient to afford about 13,000 tons per week for the hulls of vessels, and would give, roughly speaking, an output of 1,350,000 tons gross of ship-building per annum.

An increase of 5,000 tons of ships' plates and 2,500 tons of sections per week would augment the output to 2,050,000 tons gross.

Owing, however, to the limited plate-rolling capacity in this country, there are involved in getting even this restricted increase in ship-building certain readjustments, including the cutting down, to some extent, of the supply of shell steel, both to ourselves and to France.

A further increase of 1,500 tons of ships' plates per week can be obtained by rolling smaller and thicker plates in the light mills which at present roll thin sheets. This would bring the output of shipping up to 2,200,000 tons gross per annum.

Certain extensions of steel works are now in progress, but they will yield no result before the end of the year, nor their full increase before July, 1918. These will go a considerable way in helping to reach an output of 3,000,000 tons gross of shipping. In the meantime, until the adjustments suggested above have had full effect, 1,000 tons per week can be released for ship-building by a temporary reduction of our steel export to France and Italy, and by cutting down slightly the supply of plates to other Government services, but not so as to affect in any way the supply for Guns, Aircraft, Locomotives or Agriculture.

Accordingly, in view of the urgent necessity of the case, I propose that the following steps be taken :—

(1) That the manufacture of shell steel for the French Government by British firms and the manufacture of British shell be diminished so far as is necessary to obtain the 5,000 tons of steel required to feed the plate mills to their full capacity.

(2) That the cutting down of the manufacture of shell steel for France in this country should, as far as possible, be compensated by the supply of tonnage to carry French shell steel from the United States of America to France, the Shipping Controller being instructed in this sense.

(3) That in any case of shortage of steel at works engaged in making shell steel as well as ships' plates and sections, the manufacture of the plates and sections should have priority.

(4) That where the lighter plate-mills can roll plates capable of being used for ship-building purposes, this should be done in preference to rolling thin sheets.

(5) That during the next six weeks the other Departments of the Government should have their requirements of plates over ¼-in. cut down, and that the supplies of steel plates to France and Italy should for the same period be suspended, with the effect of releasing 1,000 tons of plates per week for ship-building.

(6) Priority should be given to the extension of existing plate mills and to such new mills as are in contemplation, including Appleby.

When the Minister of Munitions has had an opportunity of surveying the whole situation and of preparing further proposals, the situation can again be reviewed. In the meantime it is hoped that the carrying out of these recommendations will not cause any insuperable difficulty to the services affected.

II. Labour.

To produce the amount of tonnage above referred to it is plain that a considerable amount of extra labour will be required. For this purpose immediate steps are necessary :—

(1) The first step that I would recommend is that all recruitment or withdrawal of labour from the shipyards for the Army should cease. At the present moment all men who joined Munitions after 29 March, 1917, and are not in the Schedule of Protected Occupations, are being recruited.

(2) If full advantage is to be taken of the rolling capacity of this country it is necessary that skilled steel and blast furnace workers should be released from the Army. A list has been drawn up by the Ministry of Munitions of 823 of these, and I recommend their immediate release, which the Secretary of State for War has indicated his willingness to consider.

(3) The Admiralty has expressed the opinion that unless shipbuilding be made a fully protected industry the requisite number of men will not be forthcoming. The Secretary of State for War will explain his views to the War Cabinet on this subject.

(4) All marine engineers and fitters who are at present employed by the Ministry of Munitions should be released and transferred to the Admiralty, otherwise serious delay will take place *re* the provision of marine engines for merchant ships.

(5) Shipyard workers in the Army should be released in order to provide a nucleus of skilled labour for new yards.

(6) The War Office has promised to help with regard to the loan of prisoners of war.

(7) The Minister of Labour undertook to make a special effort to obtain as many builders as possible for the new shipyards, and will endeavour to secure 5,000 men by this process.

(8) When this effort has been made, recourse may be had to the Director-General of National Service who has expressed his willingness to help.

APPENDIX III.

Schedule of Control Orders relating to Iron, Steel, etc.

Class of Material.	Date.	Effect of Order.	Reference in Text.
Steel, pig iron, bar iron, metallurgical coke.	7.7.16	Maximum prices fixed.	pp. 90-137.
		Maximum prices revised or extended :—Steel : 31.10.16, 1.11.16, 1.1.17, 5.1.17, 30.11.17, 1.2.18, 15.2.18, 8.11.18. Pig iron : 15.8.16, 1.11.16, 17.7.17, 30.11.17. Bar iron : 15.8.16, 1.11.16, 1.2.18, 15.2.18. Coke : 1.11.16, 27.11.17, 8.11.18	
	1.4.19	Suspension of control.	
	24.4.19	,, ,, ,,	
Steel scrap	7.7.16	Maximum prices fixed.	pp. 103-4.
		Maximum prices revised or extended : 31.10.16, 1.11.16, 1.1.17, 28.8.17, 4.1.18, 20.8.18.	
	29.4.19	Suspension of control.	
Steel	20.11.16	Manufacture prohibited except under certain conditions.	p. 14.
	14.12.17	Extension of control to additional classes of steel.	
	29.4.19	Suspension of control.	
Magnesite	9.1.17	Use prohibited except under certain conditions.	p. 88.
	25.2.19	Suspension of control.	
Steel rods, bars, wire, wire rope.	24.2.17	Manufacture prohibited except under certain conditions.	
	29.4.19	Suspension of control.	
Wrought iron scrap	22.3.17	Maximum prices fixed.	p. 124.
		Maximum prices revised or extended: 28.8.17, 4.1.18, 20.8.18.	
	29.4.19	Suspension of control.	
Iron ore mines ..	24.7.17	Control by Ministry of Munitions.	
	31.7.19	Suspension of control.	
Tinplates, terneplates	24.8.17	Maximum prices fixed.	
	29.4.19	Suspension of control.	
Tungsten, molybdenite and products.	30.11.17	Dealings prohibited except under certain conditions; manufacturers, etc., ordered to make returns.	p. 84.
	17.10.19	Suspension of control.	
Tap cinder, etc. ..	15.12.17	Maximum prices fixed.	
	29.4.19	Suspension of control.	
Ironstone	18.1.18	Maximum prices fixed.	
	29.4.19	Suspension of control.	
Cast iron scrap ..	20.8.18	Maximum prices fixed.	
	29.4.19	Suspension of control.	
Forgings, castings ..	22.10.18	Manufacturers, etc., ordered to make returns.	
Refractory materials	19.11.18	Maximum prices fixed.	
	24.12.18	Control withdrawn as from 31.12.18.	
Iron, steel	7.1.19	Purchase prohibited except under certain conditions; manufacturers ordered to make returns of stocks.	p. 136.

APPENDIX IV

(CHAPTERS II AND IV.)

Imports of Iron and Manganese Ore and Ferrous Metals, January-December, 1918.[1]

Description.	Total Imports. Tons.	Imports from :—				
		U.S.A. Tons.	Canada. Tons.	France, Spain & Mediterranean. Tons.	North Europe. Tons.	India, East Indies, etc. Tons.
Iron ore	6,565,860	—	—	6,029,767	536,093	—
Manganese ore	316,471	—	—	—	—	316,471
Magnesite	42,493	—	—	37,417	—	5,076
Total	358,964	—	—	37,417	—	321,547
Shell steel	666,077	660,660	5,417	—	—	—
Shell forgings	62,793	30,179	32,614	—	—	—
Stampings and bars	778	778	—	—	—	—
Pig iron	141,979	102,958	—	—	39,020	—
Swedish steel	22,822	—	—	—	22,822	—
General steel	63,307	63,307	—	—	—	—
Ferro-silicon	25,053	2,585	14,885	—	7,583	—
Total	982,809	860,468	52,916	—	69,425	—

1 *Monthly Output Tables*, December, 1918. Copy in Hist. Rec./R./1000/95.

APPENDIX V.

(CHAPTERS III AND IV.)

Home Production and Imports of Shell Steel, November, 1917, to November, 1918.

No. of Weeks.	1917, Weekly Average for :—		1918, Weekly Average for :—										
	Nov. 5	Dec. 4	Jan. 4	Feb. 4	March 5	April 4	May 5	June 4	July 5	Aug. 4	Sept. 4	Oct. 5	Nov. 4
Home Production—													
Shell steel for British ammunition	22,688	18,947	17,147	20,485	20,658	17,737	17,775	20,752	17,966	18,286	20,551	21,196	8,718
Shell steel for Allied ammunition	7,924	6,542	4,598	3,629	2,848	2,331	2,983	2,536	1,456	2,027	2,243	1,427	1,078
Imports—													
Shell steel, including forgings	26,000	12,776	15,182	25,175	18,512	10,112	13,597	17,160	9,687	12,565	9,700	11,156	15,250
Total shell steel and forgings	56,612	38,265	36,297	49,289	41,928	30,180	34,355	40,448	29,109	32,878	32,494	33,779	25,046
Mild steel for shell parts	Figures not available.		4,052	3,701	3,310	3,282	3,057	2,788	2,326	2,129	3,039	2,906	1,649
Grand total	56,612	38,265	40,349	52,990	45,238	33,462	37,412	43,236	31,435	35,007	35,533	36,685	26,695

APPENDIX VI.

(CHAPTER III.)

Dispatches of Steel from Steel Makers during 1918.

		Weekly Average in Tons.			
		Jan. to June, 1918.		July to Dec., 1918.	
		Allocation.	Dispatches.	Allocation.	Dispatches.
Excluding shell steel, tubes and wire rods.	Admiralty—				
	Warships	37,076	4,083	46,036	2,443
	Merchant vessels		16,778		17,450
	All other purposes		13,090		9,455
	Total	37,076	33,951	46,036	29,348
	War Office—				
	Contracts	10,016	5,719	3,788	4,657
	F.W.8		4,813	5,516	4,500
	I.W.D.		217	196	100
	Total	10,016	10,749	9,500	9,257
	Ministry of Munitions—				
	Explosives*	556	441	556	250
	Guns	2,760	2,217	3,484	1,720
	Machine guns and small arms	900	563	168	470
	Trench warfare	924	858	532	607
	Mechanical warfare	3,480	2,123	1,916	2,547
	Mechanical transport	1,376	1,430	1,292	1,361
	Aircraft	3,536	3,341	2,392	3,028
	Steel works extensions	1,428	2,251	996	1,269
	Factory construction†	—	1,227	—	751
	Machine tools and cranes	1,176	1,234	1,164	919
	Railways, United Kingdom	4,536	5,723	3,444	3,737
	Railways, overseas	4,924	4,223	6,556	6,117
	Electric power supply	676	780	764	594
	Other purposes†	—	2,682	—	2,163
	Total	26,272	29,093	23,264	25,533
	India Office	492	502	552	659
	Other Government Departments	19,804	2,684	10,104	2,998
	Priority		15,760		14,657
	Allies—				
	France	6,940	6,533	9,652	7,325
	Italy	1,092	1,010	1,560	2,254
	Other	—	1,279	500	1,134
Shell Steel—					
	Great Britain — Land Service	21,448	17,300	28,080	13,500
	Great Britain — Admiralty		1,630	1,696§	1,328
	Great Britain — Mild Steel		3,351	3,792	2,082
	France	900	1,097	—	261
	Italy	3,360	1,919	3,640	1,116
	Belgium	—	117	—	—
	Other Allies	—	2	—	—
Tubes‡		7,672	1,364	7,700	1,259
Wire—rods‡		4,808	4,728	7,200	4,551
	GRAND TOTAL	139,880	133,069	153,276	117,262

* Figure here shown under allocation indicates the quantity allowed through Priority, and is excluded from the Priority allocation figure given below.

† No allocation requirements being satisfied through Priority.

‡ Information as to distribution of tubes and wire incomplete.

§ Actual dispatches for first six months.

APPENDIX VII.

(CHAPTER V.)

Output of Refractory Materials during 1918.

(*a*) MAGNESITE CEMENT AND MAGNESITE BRICKS.

——	Cement.	Bricks. (9″ × 4½″ × 2½″)
	Tons.	Number.
Year 1917—Average Monthly	329	484,494
1918—		
January	313	447,782
February	264	421,586
March	438	344,837
April	674	380,179
May	611	348,718
June	594	304,398
July	585	352,006
August	565	228,079
September	482	292,137
October	701	302,822
November	740	269,467
December	793	276,713
Total 1918	6,760	3,968,724

(*b*) SILICA BRICKS.

Year 1917—Average Monthly	10,200,000
1918—	
January	9,600,000
February	9,500,000
March	10,000,000
April	9,500,000
May	9,300,000
June	9,000,000
July	8,500,000
August	7,700,000
September	8,100,000
October	8,400,000
November	7,100,000
December	6,400,000
Total 1918	103,100,000

APPENDIX VII—*continued.*

(*c*) Dolomite and Basic Material.

——	Raw Dolomite.	Basic Material (Shrunk Dolomite)
	Tons.	Tons.
Year 1917—Average Monthly	5,669	12,740
1918—		
January	4,264	13,915
February	3,576	14,517
March	2,978	15,948
April	3,274	16,315
May	3,983	16,732
June	3,743	16,010
July	3,206	15,848
August	4,022	13,813
September	2,195	16,902
October	2,749	18,081
November	2,592	14,680
December	3,262	11,877
Total 1918	39,844	184,638

APPENDIX VIII.

Supplies of Iron and Steel, 1914-18.[1]

(Figures in tons.)

Description.	1914.		1915.		1916.		1917.		1918.	
	Home.	Imports.	Home.	Imports.	Home.	Imports.	Home.	Imports.	Home.	Imports.
Iron Ore[2]	14,867,582	5,704,748	14,235,012	6,197,155	13,494,658	6,905,936	15,027,902	6,189,655	15,044,373	6,565,860
Manganese Ore and Magnesite ..	3,437	479,435	4,640	372,724	5,140	440,659	13,094	426,309	14,942	409,278
Pig Iron	8,923,773	No Figures available.	8,793,659	959,189*	9,047,983	818,574*	9,321,778	1,098,786	9,086,352	382,057*
Steel Ingots and Castings	7,835,113		8,550,015		8,991,729		9,716,544		9,539,439	
Shell Steel	—		203,500* (*last quarter only*).	—	1,720,649*	76,197	1,746,222*	588,490	995,565*	600,752

[1] These figures are taken from *Iron and Steel Industries, 1914-18*, except where marked *, when they are taken from *Review of Munitions Output, 1914-18*.

[2] "Purple Ore" (residue of imported cupreous pyrites) is not included. In 1914-18, this amounted to 535,432—602,312—633,330—569,494 and 557,802 tons respectively.

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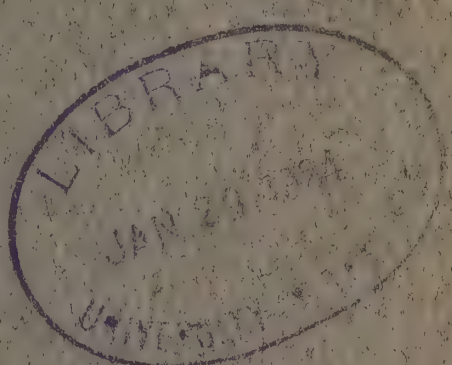
HISTORY OF THE MINISTRY OF MUNITIONS

VOLUME VII

THE CONTROL OF MATERIALS

PART III

NON-FERROUS METALS



1922

Volume VII

THE CONTROL OF MATERIALS

PART III

NON-FERROUS METALS

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CHAPTER I.

INTRODUCTION.[1]

I. The Methods of Control.

The control of non-ferrous materials was exercised by the Ministry of Munitions on three main lines—control of distribution, control of price, and development of supply, the two former being by far the most important.

The work of the Ministry was to a large extent restrictive rather than stimulative ; it was designed to prevent materials needed for British use from passing to enemy and neutral countries, to prevent supplies from being used for civil purposes when needed for the production of munitions of war, and to prevent the exceptional conditions of the market due to the war from being made a profitable field for speculators at the expense of national and Allied requirements. On the whole, restriction was imposed sparingly, and attempts were made to obtain the necessary results without developing a rigid policy of departmental control, indirect action through existing organisations, of which the London Metal Exchange Committee was the most important, being preferred to Ministry intervention, which was postponed as long as possible. But in the case of the chief metals, the growing shortage, due to the pre-war control of the industries by the enemy and to the increased demand for munitions purposes, aggravated in some cases by persistent speculation, led at an earlier or later date to control over price and destination being exercised under the Defence of the Realm Regulations. The first metal to be legally controlled was aluminium (7 December, 1915), the last was tin (26 April, 1918).

The stimulative side of the Ministry's work—the attempts to increase the output of those non-ferrous metals for which there was a growing demand—though less important, was interesting. Many experiments were made, and, as was natural, there was great variety both in policy and result. Success in some experiments was balanced by failure in others, some well-conceived schemes collapsing owing to shortage of labour, coal, and material in the last year of the war.

The third form of Ministry activity—control of the distribution of supplies—was essential. The work of allocating material among the departments concerned with the production of munitions or other war supplies, who were acting as rivals in competition for material, involved some form of centralised control in order that conflicting claims might be judged from the standpoint of national need, and supplies directed accordingly.

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[1] This part deals with the metals and materials controlled by the Non-Ferrous Metals (or Materials) Department, with the exception of tungsten and molybdenum, which will be found in Part II (Iron and Steel). For the sake of convenience, certain non-ferrous materials, such as mineral oils and oxygen, which were administered by other sections of the Ministry, are included in this part. Materials for explosives manufacture are treated in Part IV.

Besides working on these lines, the Ministry of Munitions played an important part in the gradual organisation of concerted action among the Allied powers. This development was, of course, not exclusively the work of the British Ministry, but to a great extent it developed out of Ministry action, and in some important cases was exercised through the departmental machinery already created by the Ministry to meet the British part of the problem. By the end of the war inter-Allied action had evolved a general policy of control of non-ferrous metals which included the whole world outside enemy territory.

II. The Development of Supplies.

The work of securing and developing supplies of the non-ferrous materials was essential in view of the abnormal demand for these metals for munitions and other war requirements, and the problem was complicated by the fact that the smelting and refining industries in the United Kingdom were very small owing to pre-war dependence on German supplies of refined metals.

The conditions of supply were infinitely varied, ranging from lead, where the chief sources of supply were, at the outset, under enemy control, to tin, where more than half of the world's supply was produced within the British Empire. The production of some essential metals —such as copper and aluminium—depended to a large extent upon the United States, while others, like cryolite and antimony, came from neutral countries. Where the source of supply lay outside British control, the best arrangements for obtaining increased supplies with the minimum enhancement of costs had to be discovered, often by a process of trial and error complicated by competition between the Allies, while in other cases the best methods for encouraging British producers to increase their output had to be devised.

Special efforts were directed to increasing supplies within the Empire, and freeing them from enemy control. Thus, in the case of Australian copper, most of which had gone to Germany before the war, at first the surplus, and finally the whole output was secured. An attempt was also made to develop the resources of the South African copper mines, but this was not very successful owing to transport difficulties.[1] The best example of action of this kind is the case of zinc and spelter. After the initial work of securing the Australian producers against post-war liability for their contracts with the enemy, a large scheme for supplying the Empire by an Imperial undertaking was accepted, and a grant from the British Treasury to the Dominion for the extension of production there was made.[2] At the same time the Ministry was pressing the extension of home output. In 1916 a number of schemes were submitted to the Government by English companies, with suggestions for increasing output with Government assistance. Two of these received Ministry sanction and financial support, but neither justified it, owing to labour shortage and unexpectedly high costs of production. A third scheme, based on a new process, however, abundantly justified itself.

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[1] See below, p. 16.

[2] See below, pp. 29, 30.

Lead is another case in which supplies within the Empire were developed by Ministry action during the war. Australian contracts with the enemy were abrogated by the Dominion Parliament, which made the output of a large Australian company available for British use. This, with the discovery of a new source in the Fremantle Trading Company and the increased output in Burma, secured the British position.

The system of developing production by a general subsidy to producers, which played such an important part in the Ministry policy with regard to iron and steel, was not prominent with regard to non-ferrous metals; the only example of it being the arrangements made in 1918 to supply zinc concentrates to British smelters at a reduced price in order to free them from dependence upon a ring of French producers who were raising prices against them.

As has been seen, the conditions of tin supply were very different from those of copper, zinc, and lead, as the British Empire produced 53 per cent. of the world's output, and, therefore, in 1914 there was no immediate anxiety as to supplies.

The action taken by the Ministry to secure increased supplies of the other non-ferrous metals and materials, such as aluminium, platinum, mica, shellac, etc., was infinitely varied, and no general statements can be made. It financed private firms to enable them to increase their output (as in the cases of aluminium, calcium carbide, platinum, and mica) ; it secured the exercise of diplomatic pressure to support the rights of a private firm (as in the case of magnesite, produced in Greece) ; gave financial support to mine development (as in the case of mica and shellac) ; and assisted in the construction of plant (as in the case of platinum).

Moreover, the continuance after the war of British control over non-ferrous metal industries, which had been established in the United Kingdom to meet war needs, was secured by legislation. As has been seen, these industries, though depending in many cases on raw material produced within the British Empire, had fallen largely under enemy control, exercised through the Metallgesellschaft and other financial groups in Hamburg, and enjoying financial support from the German Government. The Non-Ferrous Metals Industry Act passed in February, 1918, provided that no company, firm or individual should engage in smelting, refining or dealing with the chief non-ferrous metals (spelter, nickel, copper, tin, lead, antimony) except by licence from the Board of Trade. The Bill, though criticised in both Houses as protective in character and designed to continue government control for an undue period, was passed after some concessions (notably a great enlargement of the power of appeal against a refusal of a licence by the Board of Trade), as it appeared even to convinced free traders like Lord Balfour of Burleigh, that control of the non-ferrous metals was vital to the defence of the country in war, and to its economic independence in time of peace.[1]

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[1] *Parliamentary Debates* (1917), *H. of C.*, C. 166–206, 1011–1132, 1827–1894, 1918; C.I. 147–274, 335–462, 1013–1091 ; *Ibid.*, *H. of L.*, XXVIII, 191–218, 250–275.

III. Control of Price.

While the development and distribution of essential non-ferrous materials were the most important duties of the Ministry of Munitions at a time when to secure supplies was of infinitely greater importance than the question of price, some action had nevertheless to be taken to obviate as far as possible the artificial inflation of prices due to speculation.

As a natural result of the war the market value of many non-ferrous materials attained an unparalleled height owing to the extreme demands made on supplies by the nations who were engaged in constructing armaments.[1]

Part of this rise in price was inevitable in view of the increased expense and difficulty of production due, among other causes, to labour shortage and freight difficulties, and over this rise the Ministry could not exercise control, but cases soon appeared where prices were being artificially inflated through speculation and holding up of materials. To meet such situations it was necessary for the Ministry to exercise control, and, as will be seen in detail below, the price of all non-ferrous munitions metals and of a large number of miscellaneous materials was fixed by regulation under the Defence of the Realm Regulations. In a few cases, as, for instance, platinum and printers' metal, stocks in the hands of the trade were requisitioned at the fixed price.

The sphere within which Ministry action could directly be a controlling force was limited to the British market, except in cases such as those of tin and mica, where the greater part of the world supply lay within the British Empire. As the tin market was particularly free from speculation, the price of this metal remained uncontrolled till the last year of the war, while the mica prices fixed in 1915 were later raised as an encouragement to production. In these cases the prices fixed by the British Ministry were the dominant factor in determining world prices.

The general policy of the Ministry was to work in co-operation with the Committee of the London Metal Exchange, in order to check speculation on the British market. In March, 1916, this policy was expressed in the arrangements for a daily fixing of the prices of copper, lead and spelter by the Committee of the London Metal Exchange in consultation with the Ministry. This order had some success in eliminating speculation and in helping towards steadying the market, but it proved inadequate to later developments, and in November, 1916, in view of speculation in copper, supposed to have been due to German influence, the Ministry decided that complete control was necessary, and regulations to that effect were applied to copper. Similar reasons led to the control of spelter and lead under the same regulations in 1917, which put the control of prices of these three metals entirely in the Ministry's hands.

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[1] The figures given in Appendix II show at a glance the rise in values.

The more complex problem of securing supplies at reasonable prices in markets outside the Empire was ultimately met by the development of inter-Allied action, but before this was obtained the Ministry was able, to some entent, to guard the nation against extortionate prices by centralised purchase and by employing firms or individuals as sole agents to negotiate for the Government. This type of action may be illustrated in connection with aluminium supplies, where the situation was delicate owing to the existence of a monopoly. Speculation on the English market was controlled by the order of December, 1916, and after prolonged negotiations with Mr. Davis, of the Northern Aluminium Company of America, the Ministry was able to secure comparatively favourable contracts.[1] Very satisfactory arrangements for buying brass bars and copper bands and other non-ferrous material in the United States were organised by Sir E. Moir in 1916, at a time when there was an enormous demand for these metals for the munitions programme both at home and in the United States.[2] Similar methods were adopted to secure spelter and zinc at a reasonable price from Norway, and an expert sent to Norway by the Ministry in 1918 secured large contracts at favourable prices.

While the Ministry was able by these means to safeguard the nation to some extent against unreasonable prices, its action was only in a rather limited field, and the general control of price depended, as will be seen below, on inter-Allied action.

IV. Distribution of Supplies.

The allocation of the supplies of non-ferrous materials was a serious problem. The claims for civil trade purposes conflicted with Government needs, while a complex situation was created by rivalry for supplies between different Government Departments.

To meet the situation, a control of the distribution of supplies had to be established. This control was restrictive ; in addition to cutting off supplies from the enemy and from non-essential industry it was designed to prevent materials of which there was an acute shortage being used by any War Department when substitutes were available.

This general policy of restriction was embodied in the Export Prohibition Act of 1915,[3] in certain regulations under the Defence of the Realm Act (of which 30A was the most important) and the Priority Order of 1917. The principle of these measures was the right of the State to control materials needed for munitions of war, but the way in which such control was exercised depended on and varied with the special conditions affecting the production and use of each material. The chief successes were obtained in connection with restrictions on the use of tin, aluminium and platinum.

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[1] See below, pp. 72-75.

[2] See also Vol. II, Part III, Chap. III.

[3] The prohibition of export from Canada proved a valuable weapon in the aluminium negotiations.

In allocating the supply of non-ferrous materials, there were two distinct sections of the work: allocation among producers and manufacturers within the Empire, and the larger problem of allocation among the Allied Governments. The first problem was the concern of the Ministry alone, and the second was met by co-operation between the Ministry and representatives of the Allied Powers.

One of the interesting features of Ministry control of distribution is the great variation in the date of taking such action—in some cases the Ministry took control in 1915, and in others not until nearly the end of the war. Among the metals of which the Ministry undertook control of distribution at an early date were lead, aluminium and platinum, the use of all these being restricted in 1915. For instance, in the case of lead, where the position was serious owing to the enemy possession of the chief source of supply, the use of the metal was restricted to munition purposes, export was prohibited, and the system of Ministry licences for use of the metal was introduced. This first measure of restriction left a certain degree of freedom to manufacturers, and it was not till February, 1917, that complete control was considered essential.

Though the export of aluminium without licence was prohibited in August, 1915, control of sale and purchase was not legalised until December, partly owing to the strong opposition of British producers, who considered that freedom would have much more beneficial effects on production than any system of restriction. However, the discovery in December, 1915, that the metal was being used for civil purposes made it clear to the Ministry that it would be dangerous to defer restriction any longer, and from that date a strict control was exercised, further restriction orders being issued in June, 1916, and February, 1917.

In controlling the allocation of aluminium the Ministry had to face the difficulties of keen inter-departmental competition for the metal, and it was no easy task to make some departments recognise the necessity for economy. So severe was the shortage of aluminium that in every case where possible, even at the cost of increased weight or expense, the use of substitutes had to be insisted upon. This policy was justified by its success, and the Ministry was able to meet even the enormously increased demand for aircraft construction.

The working of control may be further illustrated by the case of platinum. Control having been imposed in December, 1915, it was possible to exercise great economy, to requisition supplies from non-essential industries, such as the jewellery trade, and to concede the claims of such important trades as that of dental manufacturers, to whom a monthly ration was allocated, while they in their turn exerted considerable ingenuity in devising substitutes for some processes where platinum had previously been considered indispensable.

Three of the important non-ferrous metals—copper, spelter and tin —were not controlled until much later. The reasons for delay in issuing control orders were different in each case. Copper distribution could not be controlled till December, 1916, owing to an entire absence of statistics as to the conditions of the trade; while tin, on

the other hand, remained free still longer because the conditions of its supply were much more favourable than those of other metals, and complete control of distribution was not considered necessary till April, 1918. Till that date, the control exercised by the London Metal Exchange in co-operation with the Ministry was adequate to the situation. It was not thought necessary to control spelter and zinc until 1917, as they were chiefly used in connection with metals already controlled.

V. Inter-Allied Action.

The policy of organised co-operation among the Allies developed slowly, its chief stimulus being the rise of metal prices in the United States markets. When the Allies all entered the market as individual purchasers, each attempting to buy the full amount of metal required for their pre-war consumption, in addition to their estimated requirements for armament purposes, prices rose rapidly, while there was the danger that some of the Allies might be left without essential materials for munition purposes, while other Allies were using such materials for their civilian trade. Co-operation was therefore necessary from two points of view, for controlling prices and for directing supplies to the best advantage of the Allies as a whole.

Both these needs became prominent at a comparatively early stage in the war, and inter-Allied combination began in February, 1915, when England and France made arrangements for the copper purchases for both countries to be made in America by England.

The next step was taken in connection with aluminium. At the outset an arrangement for supplying French needs by British purchases was discussed, but when the Russian demand developed, the situation made more formal arrangements necessary. Great Britain had undertaken large purchases of aluminium in America for Russia, but the discovery that similar demands had been made to France made definite inter-Allied arrangements for allocation essential. The result was a conference in Paris, where the needs of the Allied Powers were discussed and arrangements made for combined action which resulted in the establishment of Inter-Allied Executive Committees. These bodies were set up at various times. The Copper Committee established in December, 1916, undertook all purchases for the Allies; and the Lead Committee (1917) did valuable work in making purchases on behalf of all the Allies in Spain, and in controlling the allocation of supplies among them, while it was also able to press home the need for strict economy of the metal.

The Non-Ferrous Materials Committee of the Inter-Allied Munitions Council set up in 1918, with power to control purchases of non-ferrous materials for all the Allies, and to allocate supplies among them, shows a very definite advance in the policy of organised inter-Allied co-operation. The entry of the United States into the war made a great development possible, and the general principle of putting all the Allies on equal terms with each other and with the United States in the supply and price of the essential munitions produced was accepted in the summer of 1918.

In the pages which follow a detailed history of the control of each material will be found, and in them it will be possible to trace the development of Ministry action from the tentative experiments of the early days to the developed policy of 1918.

VI. Administrative Machinery.

The administrative machinery by which this system of control was secured was less complex and elaborate than might be expected, owing to the policy of relying as long as possible upon existing trade associations.

The Non-Ferrous or Raw Materials Department, as it was at first called, originally formed part of the Gun Ammunition Department under Mr. (later Sir) Glynn West, and was generally known as A.M.2. The Director, Mr. (later Sir Leonard) Llewelyn, was responsible for the supply of steel, copper, brass, spelter, aluminium and other metals, and thus inherited functions which had already been performed under Mr. Booth and Sir Percy Girouard at the War Office.

In August, 1916, a reorganisation became necessary owing to the growth of work and responsibility. The Raw Materials Branch became an independent section of the Munitions Supply Department and its work was divided, Mr. Llewelyn being appointed a Deputy Director-General (M) and retaining responsibility for the non-ferrous metals, while the supply of steel became the work of a separate branch under Mr. (later Sir John) Hunter, who was made Director of Steel Production. A Statistical Branch, known as A.M.2/Stats, was also formed, which later served both the steel and the non-ferrous metals departments and worked in close co-operation with the Department of Requirements and Statistics.

In January, 1917, owing to the difficulty of working a common service statistical section, which was itself a sub-section of one of the departments it served, it was found desirable to transfer the work of compiling general statistics as to demand for and output of all munitions materials to the Department of Munitions Requirements and Statistics.[1] It was hoped that these statistics would be sufficiently comprehensive to serve as a general guide to those responsible for making priority decisions in detail or allocating labour, material, machinery, etc., between various uses. The Raw Materials Branch continued to keep its own "detail" statistics, supplying to the Department of Munitions Requirements and Statistics such information as it might require for the compilation of the complete statistics of the Ministry.[2]

On the formation of the Munitions Council in August, 1917, the Non-Ferrous Materials Department became part of Group M. under the superintendence of Sir Ernest Moir, and Sir Leonard Llewelyn received the title of Controller. During this year the department developed rapidly, chiefly owing to the work involved in the control of brass and copper; new sections were formed as the control of fresh metals became necessary or the difficulties of supply increased, and the diagram given in Appendix I illustrates the final organisation of the department as it existed at the time of the Armistice.

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[1] C.R. 4467. [2] General Procedure Minute No. 68 (20 January, 1917).

CHAPTER II.

COPPER.

I. Introduction.

The position on the outbreak of war was that sufficient copper was being produced to meet the world's demands and to allow of stocks approximating 100,000 tons being held in reserve. The chief sources of supply were the United States, British Dominions (Australia, Canada and South Africa), Japan, Spain, and Portugal and Mexico. America produced about 60 per cent. of the world's production, which for 1913 totalled 1,000,000 tons. The following statistics show that for some years prior to the war little effort had been made to increase production, which served to supply all demands, and to maintain large and yearly increasing reserve stocks.

	1912	1913	1914
U.S.A. Production	557,000	546,000	504,000
Rest of world	447,000	454,000	392,000
Total Production	1,004,000	1,000,000	896,000
Stocks visible and available ..	90,000	70,000	100,000
Percentage of stocks to consumption	9 %	7 %	13 %
Average price (Standard Copper) ..	£73	£68	£60

During the first year of the war, prices, which had been as low as £49 per ton in the early months, rose slowly but steadily, reaching £66 per ton by the end of the year. This was due not to any decrease in production, but to the growing demand for munitions and to faulty methods of purchase. Private firms bought only in conformity with their manufacturing orders, while Government Departments bought separately, and by tender. Large purchases by France and Russia made great inroads into reserve stocks, while the home consumption of America and Japan increased nearly 100 per cent. on account of Allied orders placed for munitions in these countries.[1]

	Exports from the United States to the Allies.[2]		
	1913	1914	1915
	Tons.	Tons.	Tons.
England	59,678	89,456	89,814
France	71,429	67,339	105,463
Italy	18,557	30,096	47,813
Russia	3,530	3,898	16,710
Total ..	153,194	190,789	259,800

[1] American consumption increased from 271,000 tons in 1914 to 415,000 tons during 1915.

[2] *"The Ironmonger" Metal Market Year Book.*

The effect of these unconcerted operations was most marked. The market in January, 1915, opened at £57 5s. per ton, but by the following June, when the Ministry of Munitions was formed, the price had risen to £86 5s. per ton, while it was estimated that stocks in England had fallen to approximately 8,000 tons, of which a large proportion was unsuitable for war purposes.

II. Organisation of the Copper Section.

A special section of the Raw Materials Department was formed to deal with the supply of copper and copper bands. The duties of the section may be briefly set down as follows :—

(1) Purchasing raw copper and distributing it to consumers.
(2) Organising and enlarging existing works and factories for the production of copper bands.
(3) Opening up new works to increase production.
(4) Regulating the use of copper so that the metal should be used, except under special licence, only for the production of munitions of war.

The pressing need was not so much the provision of supplies of the metal as the speeding-up, organising, and creating of various works and factories for the supply of copper bands. The ammunition programme was greatly in excess of the country's capacity for manufacturing copper bands, and there was a total lack of reliable statistics as to the capacity of existing works, the different classes of work manufactured and the amount of scrap copper produced.

III. Purchase and Supply of Raw Copper.

From the beginning the section bought copper for the national factories and other works, whose whole output had been taken over by the Ministry, but the big armament firms and the regular makers of copper plate for locomotive fire-boxes made all their purchases direct. This policy, however, was open to abuse, and was seized upon by unscrupulous speculators to exploit the needs of the Ministry, so that it became imperative to eliminate private purchasing.

In November, 1915, information from reliable sources all tended to indicate that an American group had arranged to "make the market," and raise values to an almost prohibitive price. Best selected copper had risen on the London Metal Exchange, in sympathy with New York, from £75 10s. on 6 September to £87 10s. on 29 October, and by 30 November the price had mounted to £97, with every prospect of reaching a very much higher figure.

With a view to counteracting the movement the Ministry entered the market, two contracts being concluded for a total of 55,000 tons of American electrolytic copper at 20 cents per lb.—£92 per ton—f.o.b. New York. These purchases effected a saving of nearly £1,000,000 on the prices ruling a fortnight later, during the first week in January, 1916, secured a supply of the metal for the Ministry over the ensuing six months and prevented certain supplies from reaching the enemy.

Further, in consideration of the purchases, which were made in conjunction with the Admiralty, the Ministry secured, through Commander Leverton Harris of the Admiralty, an assurance from an American group that their sales to Sweden, which had been calculated to be at the rate of 1,000 tons per month, should not exceed a maximum of 750 tons per month without first obtaining the consent of the Ministry. At the same time Government contractors were instructed that contracts for quantities exceeding 50 tons of best selected or electrolytic copper were not to be placed at prices exceeding £100 per ton without the sanction of the Ministry.

During January and February, 1916, the market, under the influence of a large American speculative group, rose to £136 per ton, and promised to reach a much higher figure within a short time.[1] After an examination of the position in conjunction with the Committee of the London Metal Exchange, the Ministry arrived at a decision whereby it was thought that speculative interests might be checked. Accordingly on 2 March, 1916, the London Metal Exchange Committee issued a notice prohibiting "open dealing in the ring," the prices thereafter being fixed daily by the Exchange Committee acting in conjunction with the Ministry.

The regulation which allowed of the daily fixing of prices was made by an Order in Council on 29 February, 1916, and was published in the "London Gazette" on 1 March. The metals coming under the Order were copper, lead, spelter and iron, and the publication of the Order had an immediate effect on dealings in these metals on the London and Glasgow Metal Exchanges. The Order was supplemented by the publication in the press of a notice for general information and guidance as to the interpretation of the Order.

The notice was to the effect that the object of the new regulation was to stop speculation in metals generally, and not to restrict legitimate trading. It was pointed out that :—

(1) The regulation would not be enforced in the case of purchases made outside the United Kingdom until the metal actually reached this country.

(2) Export orders and sales to Allied and neutral countries through authorised channels would be treated as consumers' orders.

(3) It was permissible for merchants, warehousemen and retailers to replace metals unsold after 1 March, 1916, by the purchase of an equivalent quantity of the same metal, although the metal so purchased might not be the metal actually delivered against the sale.

(4) Transactions would not be permitted, except under license from the Ministry, in scrap from high-speed steel, copper scrap and brass scrap.

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[1] Minutes of Finance Committee on Economy, 25 February, 1916 (HIST. REC./R./400/37).

The London Metal Exchange and the Glasgow Pig Iron Association were authorised to grant licences to their members to close, on or before 31 May, all transactions which might be open at the time of the issue of the Order, and to point out clearly to their members that it must be understood that no transaction of a speculative nature could be carried forward in any circumstance.

The Order had a salutary effect upon prices ; it eliminated undesirable speculation to some extent, and enabled a larger, though gradually decreasing, reserve to be maintained. When the Order came into force European visible supplies were estimated at 21,700 tons, and the settlement price was £101 per ton for standard copper. By the end of July Government stocks ranged round 6,000 tons, while European visible supplies were only 12,000 tons. The price, which had risen in an excited American market during May to £145, had fallen over £30, and the market opened on 1 August at £109 per ton. The Ministry's requirements and those of other Government Departments for a period of nine months had been secured by the Raw Materials Department before the Order was put into operation, so that the rising price did not affect these supplies. Had the Order not been issued it is probable that prices would have been maintained in the neighbourhood of £150, while available stocks would have fallen to a negligible quantity.[1]

IV. Centralisation of Allied Purchases.

The system of individual purchases on account of the Allies invited speculators to operate in all metals, and the only remedy was a system of centralised purchasing, which was advocated by the Finance Committee on Economy in the summer of 1916.[2]

Already some steps had been taken in this direction. In November, 1915, M. Albert Thomas had asked the Ministry of Munitions to purchase 10,000 tons of copper in America on behalf of the French Government. Replying to this request on 30 November, the Minister asked M. Thomas what the French position was with regard to the metal, and particularly what supplies had been purchased for delivery over the next six months, and through what firms the purchases had been made. He suggested that the French purchases should be made at the same time as the British purchases in order to avoid competition.

To this communication no reply was received, and British purchases were proceeded with and duly effected. Subsequently the French requested that the 10,000 tons of copper should be bought for them, but as the market was then £15 to £20 higher, it was an extremely inopportune time for any large buyer to enter the market. Further, if the British Ministry of Munitions were to have concluded the purchase at the increased price, it would have absorbed a source of supply which was being reserved to meet the needs of British Government contractors. Before deciding to sacrifice this source of supply it was essential that the French Government should forward the

[1] Minutes of Finance Committee on Economy, 29 March, 2 May, 22 May, 1916. (Hist. Rec./R./400/37).

[2] *Ibid.*, 19 June, 1916.

information asked for in the Minister's letter of 30 November. In reply, M. Thomas stated that he had decided that the British Ministry should take charge, on behalf of the French Government, of all purchases of copper and zinc in America. French requirements were covered until May, 1916, after which supplies were to be assured them through purchases effected on their behalf by the Ministry of Munitions. Apart from the request for 10,000 tons of copper, the monthly quantity required, from May, 1916, onwards, was approximately 13,000 tons of electrolytic copper and 2,000 tons extra pure zinc.

This arrangement was confirmed at an Allied conference held in April, 1916, when it was decided, in view of the shortage of stocks, to exercise an option which the French had for 132,000 tons at 26 cents per lb., or £120 per ton, the market price being £132 per ton. The conference further agreed that all demands for copper from Italy, Belgium, or other Allied countries, received by the French Ministry of Munitions, should be forwarded to the British Ministry of Munitions, as well as any offers that might be submitted to the French Ministry.

V. Issue of Order for Control of Copper by the Ministry.

During the ensuing months it became manifest that though centralisation of Allied purchases had materially reduced the difficulties of the position it did not solve the problem.

The position was fully discussed with the trade, which agreed that dealings in the metal must be controlled by the Government in order to eliminate speculation. Another argument was that the American policy with regard to copper was directed from Frankfort, and it was part of Germany's war policy to force up the price, while every important American copper firm had sold copper to Germany for delivery after the war. Accordingly, in November, 1916, it was decided to issue an Order under the Defence of the Realm Act making it illegal for any manufacturer, merchant, or agent to deal in copper unless authorised by special permit from the Ministry of Munitions.

The Order came into force on 8 December, 1916, and at the same time a committee, selected from the principal merchants of the London Metal Exchange, was appointed to make purchases for the Allied Governments.[1] Before the formation of the committee the following joint purchases were made by the French and British Ministries :— 200,000 tons electrolytic, and 67,000 tons best selected and electrolytic copper from the United States, and the Australian production during 1917, estimated at 40,000 tons.

The American copper was purchased at 25 cents per lb., or £115 per ton, and the Australian production at £116 13s. 4d. per ton. When the Order came into force the price on the London Metal Exchange was £152 per ton for standard and £169 10s. for electrolytic copper.

On 2 January, 1917, a further Order under the Defence of the Realm Act was issued giving notice of the Minister's intention to take possession

[1] The Committee consisted of Sir Cecil L. Budd, K.B.E. (Chairman) ; Mr. R. W. Rucker ; Mr. B. E. Wenham, O.B.E. ; Mr. A. M. Stroud (Secretary).

of all unwrought copper, including copper scrap.[1] While it was not the intention of the Ministry to take over stocks of rough copper held by copper smelters, who sold the refined metal in the form of ingots, bars, etc., such firms were required to sell the whole of their output which they had not otherwise contracted to sell at the date of the Order, either to the Ministry direct, or as might be authorised by the Ministry.

The prices at which copper was taken over under these controlling Orders (which were arrived at by taking the average of the official quotation of the London Metal Exchange for the last fifteen days of December, 1916) were as follows:

	Per Ton. £ s. d.
Electrolytic (ingot, wire bar, or cathodes)	153 3 9
Best selected (all brands)	149 16 4
Tough	148 16 4
P.C.C.	147 16 4
Ingot	146 16 4
Rough copper, Bessemer	142 15 0
Rough copper, virgin	137 5 0
Rough copper, inferior Japanese slab ..	128 15 0

The copper taken over at the above prices continued to arrive in England up to the end of July, and approximated a total of 6,000 tons. In addition to these commandeered stocks, the Ministry, under the Orders, also commandeered the copper to be delivered under certain contracts by which English buyers had secured copper, in some cases for more than twelve months ahead, at the contract price plus 10s. per ton. A payment on account, usually between 80 and 90 per cent. of the estimated value, was made on the arrival of the commandeered cargoes, in order to release the copper promptly for consumption.

Consequent upon the issuing of these Orders the Copper Section had to be reorganised. The Copper Committee undertook all purchases and questions of general policy or special difficulty, and generally supervised the allocation of copper available for distribution. Mr. B. E. Wenham, the Director of the Copper Section of the Ministry, met the Copper Committee daily, and was responsible for the allocation of copper to cartridge, metal, and brass rod makers, and for the keeping of records, books, accounts, etc. Other sections dealt with the supply of copper plates, tubes, and shell band strip, with sales of copper under the instructions of the committee, with statistics, and with the collection and distribution of brass and copper swarf.

With the coming into force of the Order controlling copper, most of the purchases on behalf of the Allies were made by the Copper Control Committee, which allocated the metal in accordance with the requirements of each country.[2]

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[1] Both this and the order of 8 December, 1916, were suspended on 17 December, 1918.

[2] Though joint buying had been agreed upon, the French Government sometimes acted independently of the Copper Committee. (P.M./Gen./010.)

During the year ending May, 1917, purchases aggregating 468,000 tons were made in America and Australia on behalf of Great Britain and the Allies. Allied demands were kept distinct, but purchases were made in bulk and afterwards allocated by the British Copper Committee. The saving on the purchases made by the British Ministry of Munitions and the Copper Control Committee represented about £14,000,000 on ruling market prices.

In spite of efforts to economise copper by the introduction of cast iron fuses and lighter driving bands for shell the Ministry's demand for copper constantly increased. The quantity allocated to the British Ministry of Munitions during the 12 months ending May, 1917, aggregated 230,000 tons, and included 206,000 tons from the United States, but the requirement for the last six months of 1917 had risen to 168,470 tons. The American purchases were made by the British purchasing organisation in the United States at prices in accordance with an agreement with the Government of the United States, whereby it was decided that the price paid for copper by the American Government should be the price to be paid for Allied requirements of the metal. A complete world control of the metal was thus established.

VI. Increased Production of Copper.

The demand for copper grew so rapidly that had it not been for a largely increased production in America all the Allies' munitions programmes would have had to be curtailed. Fortunately the increased yield of ores in America was sufficient to meet all Allied requirements. The controlling factor, however, was the lack of refining capacity.

The output of copper during 1916 surpassed all previous records, and taking the average price of 27 cents per lb., the output for the year was valued at $520,000,000 (approximately £130,000,000) as compared with a value of $242,900,000 (approximately £60,790,000) for the output of 1915, and $189,790,000 (approximately £47,447,500) for 1913.

The output of refined copper from primary ores, domestic and foreign, for 1916 was estimated at 1,031,725 tons, as compared with 729,464 tons in 1915, and 720,982 tons in 1913. Production from mines in the United States for 1916 was more than double that of ten years before, and more than four times that of twenty years before; while exports amounted to 325,634 tons as compared with 270,572 tons for 1915.

The following tables of production and exports show the increasing demand by the Allies upon America during the period of the war :—

	Production.	Exports to Allies.	Prices.		Reserve Stocks on 1 January.
			Highest.	Lowest.	
	Tons.	*Tons.*	£ s. d.	£ s. d.	*Tons.*
1913 ..	546,700	172,427	87 2 6	61 15 0	47,097
1914 ..	513,500	204,026	66 15 0	51 15 0	40,351
1915 ..	624,100	270,572	86 12 6	57 7 6	77,518
1916 ..	861,000	325,634	153 5 0	85 2 6	36,799
1917 ..	844,000	426,000*	140 5 0	110 5 0	5,714
		**Estimated.*			

DETAILED EXPORTS TO ALLIES.

	1913	1914	1915	1916
	Tons.	*Tons.*	*Tons.*	*Tons.*
United Kingdom ..	59,678	89,456	89,814	82,395
Belgium	3,170	2,424	—	—
France..	71,429	67,339	105,463	150,370
Italy	18,557	30,096	47,813	50,188
Russia	3,530	3,898	16,710	22,169
Canada	16,063	10,813	10,772	20,512
Total ..	172,427	204,026	270,572	325,634

EXPORTS TO ENEMY AND ADJACENT COUNTRIES.

	1913	1914	1915	1916
	Tons.	*Tons.*	*Tons.*	*Tons.*
Austria-Hungary ..	15,468	12,049	—	—
Germany	137,120	78,883	—	—
Netherlands	79,884	56,250	1,794	2,613
Other European Countries	6,409	20,372	25,007	13,705
Total ..	238,881	167,554	26,801	16,318

In addition, considerable quantities of copper were obtained from British Colonies. The chief producer was Australia, which had an annual output of between 40,000 and 50,000 tons. Before the war most of this copper went to Germany, but in 1915 negotiations were entered into to secure the Australian surplus output, and in February 1916, contracts were concluded for the purchase of 5,000 tons of best selected Wallaroo copper, and 7,500 tons of Australian electrolytic copper for delivery during the year, at a price of £100 per ton.

Subsequently the whole of the Australian output for 1917, approximating 40,000 tons, was contracted for at £116 13*s.* 4*d.* per ton f.o.b. Sydney, which was as nearly as possible equivalent to the price paid for a purchase of 200,000 tons in America at a price of 25 cents per lb., f.o.b. American port; while for a later purchase of 67,500 tons in America on behalf of the Allies, 27 cents per lb. was paid, this being £9 per ton more than that paid for the Australian output. The output for 1918 was also purchased at a basis price of £108 per ton f.o.b. Sydney.

Of the copper fields in South Africa the two most important mines lay outside British territory. These were the Katanga mines in the Belgian Congo, and the Octavi mines in German South West Africa. The value of the deposits of these latter mines, too, was increased by the high lead and silver values contained, the production in 1912 being 6,987 metric tons of copper, 11,257 tons of lead, and 11,663 kilos of silver. Unfortunately, owing to transport difficulties and shortage of freight, it was not possible to exploit these mines. The Katanga output had been sold to merchant firms in this country before control

was established, and a large portion had been resold to customers. These contracts were carried out and any surplus produced and for which freight could be obtained, was shipped to England and taken over by the Ministry. The production of these mines increased during the war from about 25,000 tons to 40,000 tons.

The output from the Canadian copper fields approximated 34,000 tons per year, but this was almost wholly absorbed in home consumption for the manufacture of munitions of war for the Imperial Munitions Board.

India produced practically no copper, being in fact dependent, during the period of war, on the Ministry of Munitions for copper for the use of the Government Ordnance Factories, 250–300 tons per month being delivered direct from Australia on Ministry of Munitions contracts.

The following table summarises the growth of output :—

	1911	1912	1913	1914	1915	1916	1917
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
United States	492,650	554,835	548,575	525,529	676,212	881,237	856,570
Canada and Newfoundland	26,085	35,250	34,365	34,027	47,202	47,985	50,351
Mexico	54,030	70,845	52,580	36,337	30,969	55,128	43,827
Chile	29,595	37,305	39,385	70,876	47,142	64,636	75,245
South America (except Chile)	32,720	29,345	33,640	31,204	44,246	53,441	59,242
Australasia	41,840	47,020	46,058	37,592	32,512	35,000	38,100
Japan	55,000	65,500	72,000	72,938	75,000	101,467	124,306
Africa	16,980	16,370	22,510	24,135	27,000	34,572	37,315
Spain and Portugal ..	52,045	58,930	53,835	37,099	35,000	42,000	42,000
Rest of Europe	72,515	89,085	83,505	87,594	76,000	101,500	86,000
Total ..	873,460	1,004,485	986,975	957,331	1,091,283	1,416,966	1,413,056

VII. Distribution of Supplies.

The policy followed in regard to the distribution of copper was that all firms wholly engaged upon the manufacture of munitions of war were allowed to buy copper from the Ministry in accordance with their requisitions, unless the requisition seemed unreasonable in amount, or the delivery asked for unnecessarily early. In the case of firms only partially engaged on war work, enquiries were instituted as to the contract upon which the copper was to be used, and an inspector was sent to check any doubtful statements.

Every contractor who was supplied with copper had to make a monthly return showing the quantity received during the month, the quantity consumed, the stock in hand, and details of the purposes for which the copper was actually used, together with the certificates under which the various orders were manufactured, these latter being sent to the Priority Committee for examination and checking. Records were kept of all purchases made and deliveries received against each buying contract, all sales and allocations of copper, the amount of copper taken over from merchants under the Orders issued under the Defence of the Realm Act, or sold to consumers by merchants prior to the issue of the Orders. Records were also kept of all purchases made by the Copper Committee.

All copper sold or distributed by the Ministry was ordered forward by means of issue warrants, copies of which were also forwarded to the Finance and Stores Departments. In addition, forms were periodically sent to the Finance Department giving detailed particulars of copper sold or allocated for the manufacture of components. Further, a liaison officer was also appointed by the Finance Department to deal specially with sales and purchases, excepting only large contracts made abroad by the Copper Committee.

VIII. Reserve Stocks.

As has been seen, it was estimated that the total stocks of copper available in June, 1915, aggregated about 8,000 tons, of which the larger portion was unsuitable for munition purposes. World stocks at this period were estimated at 90,000 tons, and as it was then known that production was not keeping pace with demand it was recognised that these stocks would have to be drawn on until additional refinery plant was completed, and the possibility of economising the use of the metal had to be considered. By December, 1916, when the British Copper Control Committee came into being, the total world's stocks had fallen to below a month's requirements. Early in 1917 an Order for the control of scrap copper was issued and the saving effected in the use of virgin metal, by the utilisation of scrap, formed the basis for the creation of a reserve stock. Within a few months some 2,000 tons of scrap metal per month became available, and a saving of approximately the same amount of virgin metal was thus effected. By 31 March, 1918, a stock of over 50,000 tons, which represented ten weeks' supply, had been established :—

	Tons.
In Ministry store and in producers' hands ..	25,110
In consumers' hands	25,416
	50,526

There were also 10,000 tons of scrap copper in hand, representing four weeks' supply of this metal. Ministry stocks of copper in store on 31 December, 1918, had increased to 36,000 tons, this of course being due to the cessation of hostilities and the lack of demand during the period of the change over from war to peace conditions.

Losses of copper through the action of enemy submarines always occasioned grave anxiety until a reserve stock had been accumulated. During 1916 and the early part of 1917, when the metal was needed by munition manufacturers almost immediately on its arrival at a home port, the position was often serious, as for instance, in May, 1916, when the s.s. " Cymric " was torpedoed with 120,000 copper bands and 600 tons of copper on board. So low were the stocks of the metal held in this country at that time, and so urgent was the need of bands that the Director of Munitions Overseas Transport was asked to make special arrangements with the Admiralty to ensure the safe arrival of the s.s. " Celtic," then on her way from New York to England with a large consignment of 4·5 in. shell bands on board. Had the " Celtic " been lost several munition factories would have been compelled to suspend work.

The only other losses during 1916 were a consignment of 1,000 tons on board the s.s. "Rowanmore" and 150 tons on the s.s. "Arabia," both ships being torpedoed. Losses during the intensive 1917 submarine campaign of the enemy were heavy. The total losses to 30 June, 1917, totalled 8,779 tons, representing 14 consignments, and four further cargoes totalling 2,200 tons were lost during the next two months, but by this time ample reserve stocks had been accumulated in this country, and the losses, though serious, did not cause any anxiety in regard to maintenance of output of munitions.

The last loss of a consignment was in February, 1918. The total loss of metal through submarine action from June, 1915, to the cessation of hostilities amounted to 12,620 tons, representing 22 consignments, which at an average value of £130 per ton represented a loss of £1,660,600. Eighteen of the vessels were lost on the Atlantic route and four on the Australian.

IX. Production of Copper Bands.

In 1914 the only known method of making copper rings was by cutting copper tubing of correct bore into suitable widths for driving bands. There were, at the time, only two firms who were in a position to supply rings, the total average output being 80,000 per week. The tube makers, at the request of the Ministry of Munitions, gradually added to their plant both for making and cutting up tubes, while in addition contracts were placed with engineering firms to cut up tubing purchased by the Ministry. The source of tubing supply, however, was limited, as the Admiralty had a prior right to all copper tubes manufactured in the United Kingdom, and only those tubes which were surplus to Admiralty requirements were available to the Ministry for cutting into rings. As soon as the National Shell Factories approached the production stage it was recognised that the supply of rings that would be available would be totally insufficient to meet the demand, and that it was necessary to develop other methods of manufacture. Experiments were conducted for the manufacture of rings out of copper sheet and plate, *i.e.*, by pressing the plate into cups and cutting off the rings from the small tubes. The experiments were successful, and the method was developed and out of a total home production of 173,000,000 rings 49,000,000 were made by this method. Messrs. T. F. Braime & Company, of Leeds, gave great assistance to the Ministry in the development of this method, while the firm supplied 8,000,000 rings of different sizes. This method of manufacture was adopted by the Birmingham National Shell Factory, which produced nearly 9,000,000 bands.

Another method of production was developed by the Muntz Metal Company, which made a success of casting rings, and this method of producing large rings was of considerable assistance at one period.

Messrs. Fenton Brothers suggested brazed rings for the smaller sizes, and these on trial were found satisfactory and adopted. At first they were made out of plate, but later were taken out of drawn strip, a total of 4,292,000 rings resulting by this method.

At the beginning of 1917, the use of butt-printed (split) rings was authorised for driving bands on shells up to 6-in. howitzer. This method of manufacture was most economical, and as supplies could be obtained from plant not otherwise fully occupied it was widely developed, and resulted in a production of over 28,000,000 rings.

Thus from an average of 80,000 rings per week from two contractors, the home manufacture was developed until an output of 1,350,000 rings per week of all sizes was reached from the 114 contractors employed. In all 173,000,000 rings were produced, representing about 110,000 tons of copper.[1]

In addition large contracts were placed in America, 6,000,000 bands being ordered in the latter part of 1915, and a total of 14,000,000 during the war period.

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[1] Details of the output by the different methods are given in Appendix VI.

CHAPTER III.

SPELTER AND ZINC.

I. Introduction.

The situation with regard to spelter and zinc was one of the chief problems that faced the Raw Materials Department of the Ministry. While there was an abundance of ores, the smelting capacity of the Allies fell far short of requirements, and the position was further accentuated by the loss of the spelter formerly imported from Germany and by the demand for "fine zinc," which might be described as refined spelter of 99·9 per cent. purity, for the manufacture of cartridge cases and other munitions.

The world's production of spelter in 1913 was, approximately, 1,000,000 tons. Of this total America produced 320,000 tons, Germany produced 283,000 tons and Austria 21,000 tons, as compared with 58,000 tons produced by Great Britain and 69,000 tons produced by France and Spain.[1]

Requirements in Great Britain in normal times were, approximately, 200,000 tons a year, more than 70 per cent. of this being imported from Germany, Holland and Belgium. The requirements for war purposes were in 1915 estimated at 20,000 tons of fine zinc and 45,000 tons of spelter of other grades, and it appeared that this amount could be obtained from the existing smelting plant,[2] which for some years before the war had dealt with 65,000 tons of zinc ores, and 140,000 tons of crude zinc, yielding between 50,000 and 60,000 tons of spelter and fine zinc. In addition there was an average production of 6,000 tons of fine zinc from native ores. The imported ores came mainly from Italy, Algeria, Germany and Spain, and the crude zinc from Germany and Belgium. But it was necessary to provide for the balance of British requirements, *i.e.*, the metal required for civil needs, which hitherto had been imported from Germany and Belgium,[3] which had developed a special process for smelting the sulphide ores produced in Australia.

Before the war about two-thirds of the British requirements of 200,000 tons had been used in the galvanising trade, and the remainder in the brass trade,[4] but the serious increase in the price of spelter (which

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[1] D.D.G.M. 34.

[2] 57th Report of the Committee on the Restriction of Enemy Supplies.

[3] D.D.G.M. 34.

[4] The following figures of annual pre-war consumption are approximately correct:

	Tons.
Galvanising	120,000
Brass and other alloys ..	45,000
Sheets and plates	30,000
Zinc oxide	20,000
Total ..	215,000

had risen from £22 10s. 6d. in July, 1914, to £95 in June, 1915) had caused depression in both these trades. By June, 1915, it was estimated that the requirements of spelter for these two trades had fallen by approximately 70,000 tons. This decline being set off by the increased requirements for war purposes, total requirements remained much the same as in peace time, but a much larger proportion of fine zinc was required.

In addition there were the needs of the Allies. About half the French production (which normally amounted to 70,000 tons a year) came from districts occupied by the enemy, while the production in Holland, from which it was possible that the French might draw supplies, was not likely to exceed half the usual output owing to lack of raw material, coal, fireclay, and so on.

The peace time production of Russia averaged about 10,000 tons. As this output came entirely from territory in Russian Poland, which was occupied by the enemy, her normal consumption of 33,000 tons and Italy's requirement of 17,000 tons would have to be provided.[1]

The total demand on the United States production, provided prices remained unchanged, was estimated in 1915 at 675,000 tons per annum,[2] viz. :—

	Tons.
British demands	310,000
Allied requirements (estimated)	300,000
Other countries (estimated)	65,000
Total	675,000

American production in 1913 had been only slightly in excess of her normal consumption, but the United States authorities were alive to the situation, and the spelter trade took steps to meet the demand. Mines and refineries that had been closed down were re-opened and new refineries erected. While production did not cover demand until 1918, the increase was remarkable, rising from 490,000 tons in 1916 to 668,000 tons in 1917, which, with increased production in Allied countries, sufficed to meet all war requirements, together with civil needs on a scale slightly reduced from that of 1915.

II. Shortage of Fine Zinc.

The position then that confronted the Raw Materials Department of the newly formed Ministry of Munitions in June, 1915, was that, though there was sufficient ore to meet all demands, smelting capacity outside the Central Empires and occupied Belgium was insufficient.

A Spelter Section was set up whose duty it was to find and arrange for supplies of refined spelter of 99·9 per cent. purity required for the manufacture of cartridge cases, and supplies of G.O.B. (good ordinary brand) spelter for the manufacture of fuses and other brass articles,

[1] D.D.G.M. 34.
[2] 57th Report of the Committee on Restriction of Enemy Supplies, para. 21.

and also for the galvanising trade; to control supplies of Mediterranean zinc ores and distribute them to smelters; and to distribute zinc ores purchased in Australia to the various smelters in this country. Further, the section had to organise British zinc ore mines with a view to increased production, to arrange for the refining of zinc in Norway and Sweden from spelter exported to those countries, to organise the increase of smelting plant in this country, and to purchase spelter and zinc for the Allies, if need be.

The early work of the department was greatly facilitated by the detailed report which had been presented by the Restriction of Enemy Supplies Committee, and by a further report by Mr. W. R. Lysaght, of Messrs. John Lysaght & Company, Newport, with special reference to supplies of refined spelter. Both reports agreed that for purely war purposes there was no likelihood of any shortage of spelter, though civil requirements might have to be considerably curtailed, and that the chief difficulty lay in meeting the War Office and Admiralty demands for fine zinc, the demand for which for non-war purposes was very small. It was estimated that for the eight months ending 31 December, 1915, not less than 20,000 tons of fine zinc would be required, while the output in this country was approximately 500 tons per month.[1]

Manufacturers in the United Kingdom held stocks totalling about 4,800 tons, and 14,000 tons had been bought in the United States for delivery between May and December, 1915. But it was uncertain whether these latter supplies would be delivered. The American demand for fine zinc had risen from 8,000 tons to 100,000 tons per annum, while production was only estimated at from 40,000 to 50,000 tons, and many firms were trying to cancel contracts on the plea of difficulty in obtaining the hard spelter from which fine zinc is made. It was, therefore, essential to increase the production of refined spelter in the United Kingdom, to increase the output in neutral countries, particularly Holland and Norway, and to limit the use of fine zinc for munitions. It was thereupon decided that all specifications should be examined in order to reduce the demand for fine zinc to the utmost extent compatible with safety, and that similar action should be urged upon the Allies. It was hoped that in this way the total Allied demand for 99·9 per cent. purity zinc would be reduced to between 80,000 and 90,000 tons per annum.[2]

III. The Position in July, 1915.

The spelter situation was reviewed with the expert assistance of Mr. Lysaght at conferences (5 July, 19 July) at which the Admiralty and Board of Trade were represented. After interviewing the manufacturers of spelter and fine zinc, Mr. Lysaght reported (19 July, 6 August)[3] that the high price of spelter then ruling was entirely due

[1] 57th Report of the Committee on Restriction of Enemy Supplies, para. 10.
[2] See below, Chapter IV.
[3] D.D.G.M. 82.

to manufacturers' and middlemen's profits. The cost of production in 1913 was about £22 to £23 per ton for G.O.B. spelter, which included the price paid for the ore, while the existing cost of production, including the cost of ore, the price of which had not risen, was between £30 and £32. He pointed out that the market had steadied during the preceding months, and the metal was being freely offered at considerably less than £100 per ton. The panic, there was little doubt, was fostered by interested parties. Moreover, production in America had risen from 350,000 tons per annum before the war to about 500,000 tons per annum; new plants were being erected and old ones resuscitated.

Home production was also increasing, and British refiners hoped that production for the last four months of 1915 would be at the rate of 80,000 tons per annum, and that three months later it would reach a rate of 90,000 tons.

About 25,000 tons per annum was produced by Holland before the war, but, owing mainly to shortage of ores, production had fallen to half this amount. The Netherlands Government placed a limited embargo on the export of this metal, but if ores were supplied by Great Britain, the Dutch Government would allow the zinc made from such ores to be exported, and a normal supply of spelter from Holland could therefore be relied on.

The question of Norwegian supplies was more difficult. A similar embargo had been placed on the metal by the Norwegian Government, but although Great Britain only imported a relatively small quantity from Norway it was fine zinc which was difficult to obtain elsewhere.

From the data available at the time, Mr. Lysaght struck the following balance sheet :—

Production in Allied and Neutral countries for year ending 31 December, 1915.		Allied requirements of spelter and fine zinc for war purposes.	
Great Britain ..	80,000 tons	Great Britain ..	65,000 tons
America	550,000 ,,	Russia	56,000 ,,
Holland	12,000 ,,	France	100,000 ,,
Russia	5,000 ,,	Italy	34,000 ,,
Spain	3,000 ,,		
France	15,000 ,,		
Total	665,000 ,,	Total	255,000 ,,

A surplus of 410,000 tons remained for America's own munition requirements, and for the civil needs of herself and other countries. The high price of spelter had reduced the galvanised iron trade in the United Kingdom by 80 per cent., which set free a large quantity of spelter for other purposes, and, unless anything happened to prevent export from America, the position as regarded war purposes appeared perfectly secure.

IV. Requisitioning of Stocks and Output.

The price of spelter in June, 1915, had reached over £100 per ton, and brass rod makers had intimated to the Raw Materials Department that they would be unable to fulfil their contracts for the supply of rods owing to the scarcity of spelter. As an immediate measure the galvanisers' stocks of spelter, which amounted to about 7,000 tons, were bought, the purchase price being agreed at £105 per ton—the market price of the day (5 July, 1915). This purchase had the immediate effect of steadying the market and enabled brass rod makers to continue work on their contracts.

Soon afterwards, in August, 1915, the Ministry requested Messrs. Henry R. Merton & Company to sell them 500 tons of fine zinc, which was to be delivered to them under a contract with Messrs. Chance and Hunt, of Oldbury, at prices varying from £50 to £60 per ton.[1] Messrs. Merton, however, refused to sell more than a portion of the 500 tons and would not accept a lower price than £125 per ton. It was decided, therefore, to requisition the whole of Messrs. Chance & Hunt's output of fine zinc to the end of 1916. Notices were accordingly given to Messrs. Chance & Hunt to this effect at the end of August, 1915. Messrs. Merton protested that they had already sold all this metal to cartridge makers for munition work,[2] but the Ministry decided (22 October) to take over these contracts and distribute the metal to the firms. On Messrs. Merton's application to the Duke Commission for the payment of £1,800, which represented the profit they would have made on the transaction, the Commission refused compensation on the ground that no property in the spelter had passed to Messrs. Merton at the time at which the Ministry interfered and took over the metal.[3]

In March, 1916, British spelter producers were informed that the Government might require a proportion of their output for delivery between April and June, and that sales of G.O.B. spelter could only be made under a certificate from the Ministry of Munitions that the metal was required for munition purposes. Under this arrangement, the Ministry took over practically all the unsold G.O.B. spelter from March to September; subsequently, half of the available output of G.O.B. was taken over by arrangement to June, 1917. This arrangement, however, was cancelled from April, 1917, the whole of the British output from that date onwards being taken over, the arrangement being subject to three months' notice on either side. The price of £56 per ton was agreed upon with certain reservations for possible increases in the cost of labour and freight.[4]

V. Purchase of Australian Concentrates.

The annual output of Australian zinc concentrates amounted to approximately 400,000 tons, practically the whole of which was controlled by a group of German interests. The members of this group

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[1] D.D.G.M. 82. [2] N.F.M.S. 1.

[3] The firm subsequently went into liquidation and the liquidator applied to the Ministry for repayment of the £1,800 claimed.

[4] D.D.G.M. 34A.

also directly, or in association with others, owned or controlled most of the important German and Belgian smelting works (which smelted 90 per cent. of the Australian production), and they were, more or less, associated with spelter concerns in this country. Further, this group of interests controlled and acted for the Spelter Convention which governed European zinc prices.

In order to free the Australian companies from their obligation to sell their output to German buyers for six or eight years after the war, the Australian Government introduced in the House of Representatives on 5 May, 1915, a Bill entitled "Enemies Contracts Annulment." This Bill was passed, but it had to be supplemented by action in England to cover the case of the British companies. The conclusion arrived at by his Majesty's Government was that general legislation on the lines of the Australian Act was impracticable, but the desirability of approaching Parliament with the object of freeing Australian companies registered in the United Kingdom from their contracts to deliver their output to firms in Germany was recognised.

In a letter to the Minister of Munitions (28 July, 1915) the Admiralty pointed out that there were very strong financial reasons for manufacturing spelter from the Australian zinc concentrates in this country in future, instead of permitting them to be exported to Germany for that purpose. A proposal on these lines had been made soon after war broke out, but it was found that money could not be raised for a project for manufacturing spelter in the United Kingdom on a large scale from zinc concentrates unless the supply of concentrates could be assured after the war. The Admiralty, therefore, urged that the Home Government should undertake to indemnify any company entering into a contract, which was to remain in force after the war, to supply zinc concentrates to a British company for conversion in the United Kingdom, or in one of her Colonies or Dependencies, against any action brought by a firm under enemy control for fulfilment of a contract entered into before the war for the supply of zinc concentrates. The Admiralty concluded with the suggestion that a request might be made to the Lords Commissioners of the Treasury to give the necessary guarantee to enable companies or firms to undertake this work.

Meanwhile a co-operative company—the Zinc Producers' Association—in which all producers were represented and from which alien interests were excluded, had been formed to handle all zinc concentrates and ores produced in Australia.[1]

At the end of 1915 the Cabinet accepted in principle the suggestion put forward by the Rt. Hon. W. M. Hughes, that the industry should receive the support of the Imperial Government, and the Minister of Munitions was requested by the Cabinet to consider schemes for the utilisation of Australian zinc concentrates.[2]

At a conference early in 1915 a deputation from the Australian Zinc Producers' Association pointed out that though the capacity for spelter smelting had enormously increased in America, Japan, Russia

[1] D.D.G.M. 1418.

[2] December, 1915. (D.D.G.M. 82.)

and Sweden, the production of zinc ores of a grade which could be profitably handled with spelter at normal prices had not shown any material expansion, and after the war, as before it, the Australian and Mediterranean supplies must, it was held, govern the situation. America was prepared to save its smelting extensions from extinction on the termination of the war demand for spelter by giving special terms for the treatment of Australian zinc ores.[1]

The deputation laid before the conference two schemes which had been formulated by the zinc producers :—

(*a*) for the smelting of Australian zinc concentrates in the United Kingdom, and

(*b*) for the erection of works for treating the ores in Australia.

These schemes involved an expenditure of about £3,000,000. The zinc producers of Australia had already formed an association for the extension of the distillation works there and the establishment of the electrolytic process, which, when fully developed, were to handle annually about 120,000 tons of concentrates, and produce zinc of 99·9 per cent purity. They urged, however, that their enterprise could not be established unless the British Government gave a bonus on the production of spelter, which would encourage the establishment of a smelting plant in the United Kingdom to treat annually about 100,000 tons of zinc concentrates, and gradually to extend its operations to meet the unfulfilled requirements of the United Kingdom, which would mean smelting about 150,000 tons of concentrates per annum.

They asked that spelter produced in the United Kingdom from ores, concentrates, slags, etc., controlled by British owners and the produce of British possessions only, should receive a bonus from the British Government of such amount per ton as would, if the average price for spelter actually sold in a fixed period was less than £23 per ton, be equal to the deficiency between the price realised and £23 per ton, provided that payments should be made by the smelting companies to a "price equalisation fund"[2] whenever the price of spelter rose above £23 per ton. They also asked that the Imperial Government should restrict the dumping of foreign spelter or zinc products, and totally prohibit the import of spelter produced in or for enemy countries for a period of five years after the war.

The proposals of the zinc producers were on a much larger scale than the Ministry was then able to accept, but it was prepared to purchase a certain quantity of concentrates, provided English works would smelt them. On 22 August, 1916, a contract was concluded with the producers[3] for 100,000 tons of concentrates at a fixed price of £6 10s. 0d. per ton for 47 per cent. concentrates while the price of spelter was at, or over, £35 per ton, and £5 10s. 0d. per ton while the price of spelter was under £35 per ton. All variation in the zinc content from 47 per cent. was to be paid for, or deducted, at the rate of 4/- per unit.

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[1] D.D.G.M. 1418. [2] *Ibid.*

[3] Sir Leonard Llewelyn's Papers 439. (These unregistered papers are now filed in the Archives Registry.) D.D.G.M. 1418.

Meanwhile, discussion had been proceeding on bigger lines. Early in June the Rt. Hon. W. M. Hughes had attended conferences at the Colonial Office at which a definite scheme for the supply of concentrates during the war was provisionally approved.[1] The producers, however, made it clear that their agreement to supply concentrates during the war depended upon consideration being given to their scheme for the extension of works in England and Australia, and the erection of large new works in both places.[2]

It was agreed that from 70,000 to 90,000 tons of concentrates, rising to 150,000 tons annually, should be supplied during the war period at a price varying on a sliding scale from £8 8s. 0d. per ton when spelter was at or over £45, down to £5 per ton when spelter was at or below £25 per ton. The producers also suggested that the Ministry should purchase their requirements of electrolytic zinc from the Australian company at a premium of £8 to £10 over ordinary spelter.

With regard to the proposed purchase of concentrates for "after the war," it was explained to the producers that the proposal was made by the Ministry for the purpose of obtaining a guaranteed supply of concentrates, both for their own intended works at Queen's Ferry and for the existing British privately-owned works and their extensions. On 15 June Mr. Robinson, on behalf of the producers, stated that they were prepared to supply the Ministry with 100/110,000 tons of zinc concentrates yearly for a period of 10 years at £5 10s. 0d. per ton when spelter was at £23 per ton, rising 3/- for each 20/- advance in the price of spelter.[3]

A scheme for the purchase of the Australian output of spelter was also considered (9 June). The proposal was that, commencing in January, 1918, the Ministry should take for 10 years from Australian producers any spelter offered up to 45,000 tons per annum, the price for ordinary spelter to be the official London price for the month of arrival at a United Kingdom port, with a premium of £5 per ton for refined zinc, provided that in no month should the price be lower than £23 and £28 respectively. This proposal was accepted.[4]

With regard to financial assistance, the Chancellor of the Exchequer, while refusing permission for the issue of capital in the United Kingdom, where numbers of Zinc Producers' Association shareholders were domiciled, agreed, in order that the zinc distillation plants in Australia should not be hampered, to make advances through the Commonwealth Government of such amounts as might be necessary for such works, not exceeding in the aggregate a sum of £500,000.

Contracts on these lines were thereupon concluded with the zinc producers as follow :—

(*a*) 100,000 tons of zinc concentrates at a fixed price for delivery.

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[1] Sir Leonard Llewelyn's Papers 52.
[2] D.D.G.M. 1418.
[3] For the details of the agreements see D.D.G.M. 1418.
[4] *Ibid.*

(*b*) 100,000 tons of zinc concentrates annually from January, 1918, for 10 years, the price to be based on a sliding scale arrangement, with a minimum of £23 for spelter. Under this contract there was an option of increasing the amount to 150,000 tons per annum.[1]

(*c*) A maximum of 45,000 tons of spelter annually from January, 1918, and for 10 years after the war.[2]

Agents were appointed to act in Australia for the Ministry to cover the handling, sampling, etc., of the concentrates.

VI. Supplies from Norway and Canada.

On 24 July, 1915, Mr. D. A. Bremner, who had exceptional knowledge of Norwegian zinc production, was invited by the Director of Raw Materials to go to Norway and Sweden on behalf of the Ministry to make arrangements for an increase of production of fine zinc, and to negotiate and conclude contracts up to 9,000 tons in all.[3] It was thought desirable that the contract should be with one firm only, but this matter was left to Mr. Bremner's discretion. Mr. Bremner was to stipulate that for every 100 tons of spelter delivered by the British Government, the company must guarantee to return 90 tons of fine zinc. The contract must be terminable at three months' notice. The remuneration of the smelting company was to be in the form of a refining charge, which was not to exceed £12 10s. per ton of spelter delivered, or more than £14 per ton of fine zinc returned, the latter alternative being preferable. Further, His Majesty's Government was not to be liable to pay for fine zinc which could not be exported from Norway or Sweden by reason of any order of the Norwegian or Swedish Governments prohibiting the export.

Mr. Bremner's work was rendered difficult by extravagant buying at high prices on Russian account,[4] and the Foreign Office (20 August) urged on the Russian Government the desirability of placing contracts for supplies of fine zinc in Scandinavia in conjunction with the British Government, which, if desired, would undertake to supply all the spelter necessary for conversion and to permit Russia to have any quantity of fine zinc up to half the amount contracted for.[5]

Meantime an assurance had been obtained from the Norwegian Government, that dispensations from prohibitions would be given till further notice, permitting refined zinc to be exported to countries from which the raw zinc had been imported, and that dispensations for the exportation of zinc would not be given to other countries, unless they had fulfilled the same conditions as to importation of raw materials.[6]

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[1] See below, p. 45 for the later history of this agreement.

[2] Owing to the fact that the market price of spelter fell after the war below the cost of production, the amount offered under this agreement was very small.

[3] D.D.G.M. 32.

[4] Russia was offering £130 for fine zinc, and £17 per ton for refining spelter.

[5] D.D.G.M. 32.

[6] *Ibid.*

The conclusion of the following contracts was authorised by the Ministry (24 August, 2 September).[1]

1. *Sundlokken Company.*—14,000 tons of fine zinc over 1916, at a refining charge of £10 per ton, with option of renewal for 1917.
2. *Sundlokken Company.*—500 tons monthly from 1 September to the end of 1915 at a refining charge of £15 per ton.
3. *Trollhattan Company.*—6,000 tons of fine zinc during 1916, with option of renewal for 1917, at a refining charge of £10 per ton, and 2,000 tons for delivery in 1915 at a refining charge of £15 a ton.

With regard to the right to terminate contracts at three months' notice, Mr. Bremner stated it was impossible to conclude contracts on these terms. He further suggested that, as Germany was in urgent need of fine zinc, he should be authorised to secure about 600 tons per month of Tharaldsen's output, not yet sold to Germany, at a refining charge of £10. It was suggested to the Commission Internationale de Ravitaillement that this balance of Tharaldsen's output of zinc might be secured for the Russian Government, and Mr. Duke, for the Commission, agreed and authorised Mr. Bremner to secure 2,000 tons of Tharaldsen's output, starting as soon as possible, on the terms suggested.

The success of Mr. Bremner's mission went a long way towards solving the very difficult position in which the Allies found themselves placed with regard to fine zinc. He had negotiated the refining of 20,000 tons of fine zinc, to be delivered over 1916, at the low price of £10 per ton, at a time when the fine zinc market was being demoralised by the offer of high prices. The British contracts represented a saving of at least £110,000, and by the purchase of 1,500 tons of fine zinc for the Russians at £100 per ton, a saving of not less than £25,000 was effected. In addition, the supplies obtained by the Government under these contracts exerted a steadying influence over the spelter market.[2] By the end of 1915 the position was so changed that the Ministry was able to dispense with buying spelter in America for 1916, except at very favourable prices.

The demand for brass and cartridge metal increased rapidly after the formation of the Ministry, and the revised estimates of requirements of fine zinc up to the end of the year, which were received by the Department about the middle of August, showed a considerable increase. The requirement for 1916 was 27,000 tons in lieu of 20,000 tons, exclusive of the needs of the Allies. Prompt measures were necessary to prevent an actual shortage of fine spelter early in 1916. It became necessary to purchase about 5,000 tons per annum from Canada and about 3,000 tons from America, in addition to the Norwegian supplies of 500 tons per month.

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[1] D.D.G.M. 32.

[2] Trade and Treaty Cables. 1015, 1048, 1054, 1116, 1182, 1231, 1371 in D.D.G.M. 32.

On 11 August, 1915, a contract was entered into with the Consolidated Mining and Smelting Company, Canada, for the purchase of 8,000 tons of fine zinc at a price of 15 cents per lb.—£69 per ton. Further contracts were entered into on 31 January, 1916, for 2,000 tons, and on 14 June, 1916, for 6,500 tons. The company failed to deliver in accordance with contract; the chief difficulty appeared to be the amount of cadmium which remained in the refined spelter which was too high for the British specification. At a conference on 19 October, 1916, Mr. (later Sir Joseph) Flavelle, President of the Canadian Imperial Munitions Board, pointed out that the whole of the company's output came within the Russian specification, and it was decided, after consultation with the Finance Department and the Commission Internationale de Ravitaillement, that these three contracts should be transferred to the Russian Government. In addition a contract was entered into with the company in January, 1916, for 5,200 tons on Russian account. It had been arranged in January to advance the company 300,000 dollars for plant, and when the June contract was negotiated, the Ministry advanced another 400,000 dollars towards plant, the amount of these advances being repaid by a deduction per ton of spelter deliveries.[1]

By the above arrangements the fears of a shortage of fine zinc were removed for the moment, the position for 1916 being as follows[2]:—

Fine Zinc Requirements during 1916.	Tons.
Estimated requirements of War Departments ..	30,000
Leaving a balance of ..	4,000
Total ..	34,000

Supplies during 1916.	Tons.
Production of British Refineries	6,000
Norwegian Contracts:	
Trollhattan Co.	6,000
Sundlokken Co.	14,000
Canadian Contracts.. ..	8,000
Total ..	34,000

The spelter position was also satisfactory:—

Requirements of Spelter over 1916 for war purposes:—

	Tons.
For shipment to Norway for producing fine zinc ..	24,000
For primers, fuses, brass adapters and other shell parts	46,000
For condenser tubes, &c.	10,000
For sundries (munition work)	12,000
For stock to be held in this country (at least) ..	5,000
Total ..	97,000

In addition, the country was using spelter at the rate of 20,000 tons per annum for civil needs, which brought the minimum requirements of spelter for all purposes for the year 1916 to 117,000 tons. The British production of spelter, based on the figures for the last six months of 1915, was estimated at 57,000 tons, leaving a balance to be imported from America of 60,000 tons—a little over 50 per cent. of requirements.

[1] D.D.G.M. 34. [2] D.D.G.M 82.

At the Paris Conference, held during the first week of April, 1916, between representatives of France, Russia and Great Britain, it was decided that, while the French should make their own arrangements for fine zinc requirements, all supplies of zinc for Russia should be purchased through the British Ministry of Munitions. This raised fresh difficulties for the Department, as Russia's needs for the year were given as 20,000 tons, which brought the British Ministry's requirements of fine zinc up to 50,000 tons per year, against the 34,000 tons estimated for 1916.[1]

VII. Schemes for Increasing British Production of Fine Zinc.

The Committee on the Restriction of Enemy Supplies had reported as their opinion that "Great Britain ought to be self-contained in respect of the manufacture of articles such as spelter and zinc, which were essential for the waging of war. If supplies from the United States were cut off a situation of the utmost gravity would arise. Such a contingency may be unlikely, but to have to depend so largely on a neutral country, however well disposed it may be, is undesirable. Further, the existing supplies are clearly short of the world's needs, and many sections of the brass and galvanising industries must be seriously affected until this deficiency can be mitigated." But for the country to be self-supporting in these two metals, large works would need to be erected to deal with Australian zinc concentrates, the maximum efficiency being attained by works capable of treating from 20,000 to 30,000 tons of ore per annum. They would have to be carefully planned and laid out, and would not start producing until two years from commencement of erection.

As a safeguard against the failure of foreign supplies of fine zinc, it was essential to encourage British makers to increase their production as quickly as possible. Estimates showed a total production of about 6,000 tons of fine zinc in the United Kingdom in 1915. The firms producing at this time, and their production, were :—

	Tons.
Messrs. Brunner Mond & Company ..	1,600
Brands Pure Spelter Company	1,600
New Delaville Spelter Company	1,800
Messrs. Chance & Hunt	600
	5,600

Proposals from Messrs. Chance & Hunt and the New Delaville Company, which had been approved by Mr. Lysaght, were submitted by the Director of Raw Materials to Sir Frederick Black (13 August, 1915). The former company proposed to erect forthwith two additional units, capable of increasing their output of fine zinc (99·95 per cent. quality) by 1,500 tons per annum. The Government was to provide the capital required, not exceeding £35,000. In return for this concession, Messrs. Chance & Hunt were to supply the whole of the output of the new units at cost price plus a commission of £5 per ton.

[1] D.D.G.M. 82.

The New Delaville Company proposed to erect two additional zinc refining furnaces at their own expense, conditional upon a sum equivalent to one-eighth of the amount expended on the new plant being refunded them. In other words, if the plant cost £30,000 the Government would have to provide £3,750 (on completion of the work). These two furnaces would increase the company's output of fine zinc and spelter by approximately 40 per cent—from 630 tons per month to 880 tons.[1] These proposals were approved by Sir Frederick Black, by the Director of Munitions Finance and the Minister, and the agreements were entered into with the firms in September, 1915.[2]

A proposal put forward by Messrs. Stewart & Lloyd for increasing the supply of spelter was not approved, as it entailed much heavier obligations on the part of the Government.

Towards the end of August, 1916, a deputation representing British zinc mine owners, attended at the Ministry to urge the erection of additional smelting works.[3] Their case was that, although Great Britain annually consumed about 200,000 tons of spelter, valued at about £5,000,000, only about 60,000 tons were produced in this country, of which only 6,000 tons were smelted from British ores. They pointed out that the zinc mines in this country were capable of considerable development, that for some years they had been languishing for want of sufficient support, and that there was a danger of the mines closing down permanently. The explanation of their failure to compete with foreign ores was that the native product being sulphide ore was not so suitable to existing refineries as the imported calamine; that the mines were scattered and the individual output small; and that, in consequence, they were in the hands of the refiners. The mine owners proposed that the Government should assist the home industry by erecting, at a convenient central spot, a refinery capable of smelting not less than 20,000 tons of ore per annum. All the mine owners in the country were prepared to form a company to work the undertaking, and to be paid for their ore out of the profits of the company, after a sum for interest and redemption had been set aside for payment to the Government. For the economical working of the sulphide ores it would be necessary to install suphuric acid recovery plant and this would add considerably to the cost of the plant. Their estimate of the cost of the complete works was £150,000, and for working capital another £50,000 would be required. Spelter would be produced at the rate of 10,000 tons per annum, and a considerable quantity of sulphuric acid would also be produced.

No action was taken on these proposals at the moment, but, as will be seen below, the interests of the mine owners were secured under the contract with the National Spelter Company in May, 1917.

VIII. Adoption of Fricker Process of Refining Spelter.

In the autumn of 1916 a special method of refining G.O.B., or hard spelter, to fine spelter of 99·9 per cent. purity, proposed by

[1] C.R.V./Gen./2153. [2] D.D.G.M. 34. [3] D.M.R.S. 510A.

Mr. G. C. Fricker, of Messrs. Fricker's Metal Company, Luton, was investigated. Samples of a trial order of 19 tons were forwarded to Woolwich, and the analysis showed that only traces, too small to be determined, of impurities could be found. Thereupon, Captain Tulloch, head of the Spelter Section of the Ministry, visited the works at Luton, to ascertain whether it would be possible to install a plant to produce large quantities of refined zinc. The Raw Materials Department reported that the furnace was of exceedingly simple construction, being nothing more than four large crucibles to act as condensers, and the pots being deep the zinc was distilled off from the surface.[1]

Mr. Harbord, the Ministry's metallurgical adviser, reported that though the process would not be economical as regards fuel consumption, the zinc losses in the process would be low, and the furnace was so constructed that it would involve very small capital cost and would in every probability give excellent results. Mr. Fricker recognised the difficulties and expense of transport in connection with any large extension of the works at Luton, and accepted the Ministry's suggestion that, in consideration of a small royalty per ton, he should put his designs and experience at the disposal of the Government. The Director of Raw Materials suggested that an all-round bonus of 5s. per ton be offered Mr. Fricker, with a minimum fee of £1,000, which would cover the royalty on the first 4,000 tons produced, and this was agreed to on 10 November, 1916.[2]

The firm of Messrs. Stewart & Lloyd, Ltd., was chosen by the Ministry's advisers to work the process, and in their experiments they found that they were able to produce the refined spelter from hard spelter, which was cheaper and much more easily obtainable than G.O.B. In January, 1917, they proposed that the Ministry should take over their stock of hard spelter, about 24,000 tons, at the purchase price, and that they should purchase further, on account of the Ministry, up to the capacity of their works for twelve months. Their proposal was agreed to by the Ministry.[3] The cost of production of fine zinc from hard spelter was not to exceed £15 per ton, and a contract was entered into on these terms. During the first year, from April, 1917, to March, 1918, Messrs. Stewart & Lloyd produced 4,766 tons of refined spelter from hard spelter, while another firm produced 205 tons during the same period.

Under a subsequent contract (April, 1918), Messrs. Stewart & Lloyd purchased hard spelter from the Ministry at £47 per ton, and returned G.O.B. and 99·9 per cent. spelter at £57 per ton and £66 per ton respectively. This was a most advantageous contract from the Ministry point of view, as the cost of the hard spelter was only £37 per ton, delivered to Messrs. Stewart & Lloyd's works, thus making the cost of their output about £45 10s. for G.O.B., and £54 10s. for 99·9 per cent. quality, as against an average price in America of £38 for G.O.B., and the price of £56 per ton and allowances, paid to British producers, this latter price being subject, for the last six months of

[1] D.D.G.M. 844; M.I.D./R./1339. [2] D.D.G.M. 844.
[3] Sir L. Llewelyn's Papers 90B.

the year, to a Government subsidy of £5 per ton additional to the contract price. After 25 March, 1918, about 1,000 tons of fine zinc were produced per quarter under this method, the average saving to the Government being at least £10 per ton.

The need for refined spelter having passed with the cessation of hostilities, Mr. Fricker, on 19 December, 1918, accepted the cancellation of his agreement, and one month's notice to terminate their contract was given to Messrs. Stewart & Lloyd on 15 March, 1919.

IX. Proposals for the Erection of a National Spelter Factory.

In May, 1916, a proposal was put forward by Messrs. Chance and Hunt to erect works near Birmingham for the refining of spelter by the special process perfected and owned by them,[1] and on 13 June the Ministry accepted the firm's proposal to erect a new refinery at an estimated cost of £230,000. Messrs. Chance & Hunt were to be paid a fee of £10,000 for designing and superintending the construction of the refinery, and were also to receive a fee of £4 per ton on the refined zinc delivered under the contract, which was for 20,000 tons of 99·9 per cent. zinc, the Ministry to supply unroasted concentrates to an analysis to be agreed upon. On the termination of the contract the site and refinery were to revert to Messrs. Chance & Hunt.

Until the refinery was capable of handling Australian concentrates, Messrs. Chance & Hunt were to work on G.O.B. spelter to be supplied by the Ministry. The Ministry was advised that it would take 2½ tons of Australian concentrates to produce 1 ton of refined spelter, and the estimated cost under the contract was as follows :—

	£
Amortisation and redemption	17
2½ tons of concentrates at £12 per ton	30
Labour costs	8
Roasting costs	3
Total ..	£58

This compared with a purchase price in Norway of £90 per ton. The scheme had the advantage over the Norwegian contract in the matter of saving of exchange, the smaller risk of transport and the benefiting of home industries.

On 20 June, however, Messrs. Chance & Hunt wrote stating that their operating costs would be approximately £30 per ton, more than twice the estimate given when the scheme was first discussed, and as the company was unable to give any guarantee as to the cost, it was agreed to abandon the scheme, meet expenditure already incurred by the firm, and cancel the contract.[2] The matter was concluded by Treasury sanction being obtained for the payment of a sum of £2,957 4s. 6d. to Messrs. Chance & Hunt in full compensation for cancellation of the scheme.[3]

[1] A.M.2/485. [2] A.M.2/485 ; 94/Z/117. [3] A.M.2/485.

Concurrently with the negotiations for the purchase of concentrates, the proposals put forward by the Australian producers for the erection, with financial assistance from the Government, of national smelting works in England, which had been accepted in principle by the Government,[1] were being considered by the Board of Trade and the Ministry of Munitions.

Broadly, the scheme submitted by the Zinc Producers' Association involved a capital outlay of (*a*) £850,000 for plant and works, and (*b*) £150,000 for working capital. The amount under (*a*) was to be provided by the Government at 5 per cent., but one-half was to be debited as a loan to the participating producing companies; the amount under (*b*) was to be found by the Government, at 6 per cent., and the producers in equal shares. This capital would allow of the erection of works capable of dealing with 100,000 tons of concentrates per annum. The first unit was proposed to be erected at Queen's Ferry, in conjunction with the Government sulphuric acid works there, and other units as and when desirable.

Important questions, both of policy and trade, arose out of these proposals. Apart from the general question of policy, there were many financial features requiring careful consideration, and the scheme was put before the Finance Committee on Economy. The main issues were as follow :—

(*a*) That smelting plants erected in war time involved abnormal capital expenditure, and extra revenue might not compensate for this ;

(*b*) Prohibition of capital issues had forced the zinc producing companies to use their own financial resources to complete great producing works in Australia, so that they were not able to find new capital ;

(*c*) Zinc distillation required much operative labour under adverse conditions, and amenities to help the workers to give continuous service, with direct financial interest in working result, if possible, should be regarded as essential subjects for expense.[2]

The committee agreed (17 July) that a Government veto on any alien endeavour to obtain control of supply was essential, but that there should be complete freedom for the management of the spelter works to develop research, "deal with the workmen and their amenities, and pay salaries for brains considerably in excess of Government ideas of the value of expert staff services." The committee were of opinion, therefore, that the works management should be in the hands of a company, the Government taking power to prevent the infusion of alien influence behind the management. On this understanding, the committee unanimously agreed with the principle that spelter and zinc should be produced wholly within the Empire, reserving their opinion on the particular question as to the exact source of supply of raw ores and the locality in which the refined metal should be produced.

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[1] See above p. 27.

[2] Minutes of Finance Committee on Economy, 10 July, 1916. (HIST. REC./R/400/37).

The Board of Trade also had under consideration a proposal by Mr. R. Tilden Smith, of the Swansea Vale Spelter Works, who had command of Burmese ore concentrates, and was prepared to erect works at Avonmouth to smelt 100,000 tons of concentrates yearly. He thought it essential that the Empire should produce its own requirements of spelter, and the terms he proposed, which were set out in a letter to the Board of Trade, dated 15 September, 1916, were as follows: -(1) A Government loan of £500,000 at 5 per cent., to be redeemed, commencing two years after the war, by annual payments of 10s. per ton of spelter produced; (2) the Government to pay excessive cost of the first one-third constructed in war time; (3) the Government to have the right at any time to take over the works, (*a*) keeping 10 per cent. on the cost of production of the metal, or (*b*) commandeering the output of the works at 10 per cent. in excess of cost of production.

> "I have given very anxious consideration," Mr. Smith stated, "to the improvement of the conditions of men employed at spelter works. Since the beginning of zinc smelting in this country the conditions attaching to employment in this particular industry have been in the nature of a scandal, with the result that in the past a considerable section of the labour recruiting has been of a more or less undesirable kind, such as the stoker, for instance, who, because of the conditions of his work, is embittered against his employer and society in general . . . . At Swansea Vale the provision made to minimise the unfavourable conditions has been very successful and this particularly applies to the new plant . . . . I have under consideration a scheme for still further improvement not only in regard to workmen's health but in wages also . . . . I am about to invite the co-operation of the labour representatives to discuss the subject . . . . I believe that at present we pay a higher wage than any other smelter in this district although the conditions with us are more favourable to the workman."

On 28 June, before Mr. Smith made his proposal, the Minister had in a conference given his general approval to the proposal that, attached to H.M. (Acid) Factory at Queen's Ferry, a roasting plant of the most modern type should be erected to treat from 35/50,000 tons of zinc concentrates per annum at a cost for four units of, say, £80,000, while he had also approved the preparation of plans for the erection of a smelting plant at Queen's Ferry to deal with roasted concentrates at an approximate capital cost of £520,000.[1]

In the meantime the zinc producers were prevailed upon to vary their July proposal on the following lines. Working capital was to be found by the producers, while capital for the plant was to be found by the Government and to be repaid over a fixed period with interest at 5 per cent. by an annuity. The plant was to have a maximum capacity of 50,000 tons of concentrates. The concentrates were to be sold to the company by the producers on terms identical with the

[1] D.D.G.M. 1419.

"post-war contract" with the British Government. (This included a guarantee of £23 as a minimum for good ordinary brand virgin spelter.) If any loss was incurred the producers were to be responsible to the extent of 7s. 6d. per ton of concentrates, while all profits were to go to the producers, subject to certain reserves. The technical business of control was to be in the hands of the producers with provision for Government representation while any part of the loan was outstanding. The British Government's interest in the business was to cease on re-payment of the loan, but it was to have at all times the first call on the company's production and complete control in time of war. Spelter and other products were to be sold through the Zinc Producers' Association's organisation.[1]

The actual position in August, 1916, when these various schemes were being considered, was summarised as follows :—

	Tons.
Capacity of existing works for smelting Australian concentrates	15,000
Extensions to existing works to be completed by March, 1917	53,000
Plant to be erected at Queen's Ferry	35,000
Proposal that one or two further units should be installed capable of smelting an additional.. ..	70,000
	173,000

In addition, the Central Zinc Company consumed 20,000 tons of concentrates per annum which they obtained direct, and they would not take any of the concentrates contracted for by the Government. Apart from Queen's Ferry, where erection of the plant had not begun, none of the works in the United Kingdom were under any legal obligation to take Broken Hill concentrates, and it was possible that the Government might have considerable quantities left on its hands.

With regard to production of spelter, the position was as follows :—

	Tons per annum.
Production from calamines and residuals	66,000
New extensions to existing works	20,000
Queen's Ferry unit	14,000
Central Zinc Company	8,000
Additional units (to be erected)	26,000
Total of spelter to be manufactured in Great Britain	134,000
Spelter to be delivered under Australian contract ..	45,000
	179,000

Assuming consumption to be at the rate of 200,000 tons per annum, if the schemes under consideration were adopted only about 20,000 tons would need to be imported, and this could easily be obtained from Belgium or America. Further, the manufacture of spelter on a large scale from concentrates would be associated with the manufacture of cheap sulphuric acid, which might be an even more valuable asset to the country than the production of spelter. The newly erected sulphuric acid plants would be supplied with the cheapest raw material,

[1] D.D.G.M. 1419.

while Germany would be largely deprived of her cheap raw material both for the production of sulphuric acid and spelter. Cheap sulphuric acid would greatly assist the development of various large chemical industries, such as those built up in Germany on the basis of cheap acid. The adoption of the smelting schemes would absorb practically the whole of the zinc concentrates, apart from those reserved for Belgium and those smelted in Australia, and would prevent Australian concentrates from being available in large quantities after the war for Germany; unless the production of spelter was undertaken in the United Kingdom on such a scale as would practically control the whole supplies of concentrates mined within the Empire, it was thought to be doubtful if much permanent good would have been effected by the money already expended. Finally, nearly all the spelter required for home consumption would be produced within the Empire.

Mr. Tilden Smith urged that the erection of a national spelter works on a site at Avonmouth was in every way more desirable than erecting a plant at Queen's Ferry, and that as a large sulphuric acid plant was being erected there, and as zinc ores would, after the war, form the cheapest source of sulphur supply to enable sulphuric acid to be made at a profit under peace conditions, the erection of another smelting works in connection with this plant might well be considered. The proposed works might have a capacity of approximately 80,000 tons of concentrates per annum.

An adjusted proposal was made by Mr. Smith, following a conference between representatives of the Board of Trade and the Ministry of Munitions.[1] The Finance Committee on Economy, which had been asked to consider the financial aspect, urged the introduction of the best commercial management that could be obtained against the principle of Government ownership and official management.[2] The Government were not prepared to take responsibility for the management or control of these smelting works, although they were willing to lend the capital; this was the only financial obligation the Government were willing to undertake.[3] This necessitated special attention to the system of control which would be necessary to prevent alien or other improper influence being exercised in the management. A direct representative of the Government on the Board of Management would be regarded as essential. The provision of Government money would enable the Government to stipulate for fair, and yet strict, powers to examine the record of the company, to detect any insidious endeavour to obtain control by aliens, and generally to maintain a close supervision over the operations of the company. All these arrangements were to be incorporated in the agreement to be made with the party by whom the zinc was to be made. The Finance Committee authorised an outlay of from £5,000 to £15,000 on the technical work of preparing plans and specifications (25 September), and laid stress on the need of efficient control of expenditure in the constructional

[1] D.D.G.M. 1419.

[2] Minutes of Finance Committee on Economy, 11 September, 1916. (HIST. REC./R./400/37).

[3] 18 September. The question had been considered by a Cabinet Committee.

stage. The scheme was intended to provide and secure to the Government the minimum quantity of zinc which they considered should be available for government purposes in case of national need at any time, even in time of peace ; it was not intended to provide the whole zinc requirements of the country.

On 11 May, 1917, a contract was signed by the President of the Board of Trade and the Directors of the National Spelter Company for the erection at Avonmouth of spelter works for the smelting of zinc ores and concentrates and the refining of spelter; and extracting sulphur from the concentrates to be utilised in the manufacture of sulphuric acid.[1] There was an agreement on the part of the company to take up to 100,000 tons of Australian concentrates per annum in consideration of a Government loan of £500,000 for the erection of the works and plant. The works were to be laid out to be capable of treating 50,000 tons of concentrates a year in the first place, and were to be further extended within five years from the conclusion of the war to treat up to 100,000 tons of concentrates per annum. The company were to provide a staff who would, under the instruction, direction and control of the Ministry, act as agents of the Ministry.

In respect of all concentrates roasted, the company were to bear the actual cost of roasting and handling, but be credited with 75 per cent. of the value of the sulphur contained in the concentrates, the value being based on the average current market price during the month of delivery of Spanish pyrites c.i.f. any port in the United Kingdom. The company were also to be credited with half the cost of handling the concentrates ex ship to the roasters. This allowance was not to be more than 6d. per ton.

The price of spelter was not to be less than £23 per ton, and the Minister was entitled during the war period to take it over at market price, and, for the time being, to control all spelter produced by the Swansea Vale Spelter Company, or any other works of which the company might have acquired control.

The company were for ten years from January, 1918, to take 25,000 tons annually of Australian zinc concentrates upon the same terms and conditions as agreed between the Board of Trade and the zinc producers, and with a view to increasing the mining of zinc ores in the United Kingdom the company were to treat native ores up to 10 per cent. of its capacity on fair and reasonable terms. Further the company were not, without the consent of the Ministry, to treat ores derived from outside the British Empire to any amount exceeding 15 per cent. of the capacity of the works.

X. The Situation at the Beginning of 1917.

Owing to the decision of the War Office, early in1917, to rely upon the huge stock of small arms ammunition which had been accumulated, and to reduce demands for fresh supplies, it was anticipated that British requirements of fine zinc for the first half of 1917 would not be more

[1] D.D.G.M. 1419.

than 20,000 tons ; further, under the Fricker process, good ordinary brand and hard spelter could be refined cheaply and readily without the erection of expensive plant.[1] In consequence, Great Britain became partly independent of foreign supplies of refined spelter, provided sufficient G.O.B. or hard spelter was available. Contracts for refined spelter in America and Scandinavia showed a surplus over requirements of about 10,000 tons, and it was decided to transfer to Russia (whose requirements for the first half of 1917 were set down at 24,000 tons) 10,000 tons of the Scandinavian output of fine zinc, as this could be sent into Russia either overland, by a protected sea route, or across the Gulf of Bothnia. A certain amount had already been so transferred because, owing to submarine activity, extreme difficulty had been encountered in getting the refined spelter from Scandinavia to England. This suggestion had advantages from a military and transport point of view, and no financial difficulty presented itself on the score of possibly insufficient credit in Scandinavia, as, by a simple exchange of metal for metal Russia could pay us for our American purchases and take Scandinavian metal to a corresponding weight.[2]

In order to secure the supplies required from January to June, 1917, which were estimated at 5,000 tons a month, Messrs. Morgan were instructed in 1916 to obtain 15,000 tons in the United States, the balance of 15,000 tons was to be secured from British manufacturers. The rest of Russia's requirements were to be secured from Japan.[3]

XI. Control of Spelter by Order.

In January, 1917, the Parliamentary Secretary, Sir L. Worthington Evans, urged that it was necessary for an Order under the Defence of the Realm Regulations for the control of spelter to be issued.[4] The Director of Raw Materials thought that, as copper was controlled and brass was probably also to be controlled, it was not necessary to control spelter (30 January, 1917).[5] Owing to the shortage of steel, the galvanising trade was on a small scale, and the use of spelter, except as an alloy with copper, was practically confined to ship plate for the Navy and mercantile marine. He thought that the amount of correspondence and licensing which would be necessary to make the Order effective would be considerable.

The Parliamentary Secretary replied that the control of spelter was desirable in order to obtain definite knowledge of the national requirements of spelter and brass.[6]

> "At present the national requirements for brass are partly met by purchases of brass made by the Ministry, partly by purchases of spelter and copper made by the Ministry, and partly by similar

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[1] 94/X/197.
[2] 8 December, 15 December, 1916 (Sir L. Llewelyn's Papers 90B).
[3] D.D.G.M. 34A. [4] C.R.V./Gen/932.
[5] C.R.V./Gen./932 ; Sir L. Llewelyn's Papers 52A.
[6] C.R.V./Gen./932. On 1 March the Board of Trade stated that owing to the disorganisation in the galvanising trade they could not give a reliable estimate of the trade requirements of the United Kingdom. (D.M.R.S. 510A.)

purchases made by manufacturers, but the Ministry has no knowledge whether the programme is, in fact, covered by these purchases, or whether a shortage exists which will be disclosed too late to be covered. The Materials Department have failed to produce any statistics showing what the total requirements are, and so cannot show that they are covered by supplies, and so long as the balance of Home production of spelter is not under control of the Ministry, and so long as the Ministry is relying on some unknown and uncontrolled private importers to import 5,000 tons per month, there can be no certainty that supplies will equal requirements. . . . . Morgan's cables show how difficult it is to procure spelter for early delivery."

Subsequently it was decided that if the base metals, copper, spelter and lead, were controlled it would not be necessary to control brass. An Order controlling spelter was therefore published on 23 March, under which sales and purchases of spelter were prohibited except under licence from the Ministry. The Order forbade the use of spelter except for Class A orders, and required returns of contracts, sales and stocks.[1]

Later, owing to scarcity of zinc oxide and lithopone, it became necessary to control these commodities. The bulk of the product was imported from abroad, and it was sufficient for control if the definition of the Spelter Order of 23 March, 1917, were widened to include these materials. This was agreed to by the Minister and an Order for control was issued on 22 January, 1918.[2]

XII. Proposal to Smelt Australian Concentrates in America.

In February, 1917, a proposal was put forward by the Producers' Association Proprietary, Ltd.,[3] to buy spelter concentrates in Australia and have them smelted in the United States. In support of his proposal, Mr. Robinson pointed out that the Ministry was paying £6 10s. 0d. per ton for concentrates; that 2½ tons of concentrates were needed to produce one ton of spelter; that the charge for smelting in the United States would be about £4 per ton; and freight from Australia to America about £5. On this basis the cost of spelter in the United States would work out at £42 12s. 6d. per ton or lower if concentrates could be bought cheaper, as appeared probable.

After discussing the matter with the Assistant Financial Secretary, the Raw Materials Department came to the conclusion that if freight could be procured, and if Australian producers would accept £4 19s. 0d. per ton for the concentrates, the offer of the American Zinc and Lead Smelting Company to treat and handle the whole, pay rail and freight from and to Atlantic ports, at a total charge of 45 dollars per ton, might be accepted for smelting 50,000 tons of concentrates. This proposal, which involved an expenditure of about 2,250,000 dollars in the United States from May to December, 1917, would secure 18,000 tons of G.O.B. spelter at £45 per ton, £5 per ton less than the price

[1] C.R.V./Gen./932. [2] *Ibid.* [3] 94/Z./196.

paid to English smelters, but the Treasury required further information before sanctioning the scheme (15 March, 1917), as it did not appear necessary to contract so far ahead as the end of the year, and in view of a reduction in Russian requirements.

On further consideration the Ministry decided not to proceed with the scheme. Including freight from Australia and reckoning smelting charges at 38 dollars, the spelter would only be produced at £45 if everything went according to plan, while Messrs. Morgan were then buying at £45 15s. 0d. per ton. Moreover, it would be dangerous to rely on a contract that did not provide for regular monthly deliveries.[1]

XIII. Shortage of Zinc Concentrates and Calamines in 1918.

For their production of approximately 5,000 tons per month British smelters relied mainly upon zinc concentrated from Australia, and calamines from the Mediterranean. Owing to tonnage difficulties, the shipment of concentrates had to be almost entirely suspended from the end of 1917. The producers, therefore, had to rely upon Mediterranean shipments, and in February, 1918, with the approval of the Ministry, they formed an association for purchasing ores, eliminating competition among themselves. In April, 1918, the Mediterranean ore producers (French companies operating in North Africa, Sardinia, Greece and Spain), who had formed themselves into an association under the ægis of the French Government, asked for an increase of one franc per unit on all zinc ores. They proposed to increased the output of calamines from 20,000 tons a year to 40,000 tons a year, but pointed out that their Government would look to the British Government to provide coal for the proposed increased output, in addition to maintaining a supply of coal for the existing output.

At a conference with Ministry officials, British producers pointed out that every franc per unit increase above the then prices for Mediterranean ores meant an increase of £5 per ton of spelter, that is a price of £61 per ton, plus certain allowances amounting approximately to £2 per ton for British spelter as against a price of about £33 per ton f.o.b. America. If the Ministry were unable to pay the increased price of £5 a ton the whole industry would have to close down[2]. Further, as furnaces when shut down were rendered absolutely worthless for future use, it would be two years at least from the time of peace before any Australian zinc concentrates could be smelted in this country.[3] Moreover, though buying in America would save tonnage and money, it was argued that American prices were likely to rise, that financing American purchases was difficult, and that the closing down of the smelting industry in Great Britain would render the maintenance of the zinc mining industry and the revival of the galvanising trade after the war impossible.[4]

Owing to the suspension of shipment of Australian concentrates, the only ore available was from mines owned by French companies operating in North Africa, Sardinia and Greece, and a few small mines

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[1] 94/Z./196.
[2] D.D.G.M. 702.
[3] May, 1918. (D.D.G.M. 702).
[4] C.R.V./Gen./2170.

in Spain. To enable all the furnaces then working to be kept in operation a monthly supply of 12,350 tons of ore was needed. The average quality of the ore offered by the Mediterranean producers compared unfavourably with Australian concentrates—40 per cent. as against 47 per cent. zinc content. In refusing an offer from the British producers of 4·80 francs per unit instead of 5·80 per unit, the French representatives admitted that best quality ore was going to French works, and incidentally mentioned that the price for spelter in France was £100 per ton as against a British price of approximately £58 per ton, including allowances (7 May, 1918).

A departmental inquiry followed, in which the Treasury, the Board of Trade, the Non-Ferrous Materials Department, the Controller of Munitions Contracts, and the Controller of Commercial Finance were represented. It was decided to ask, and the Treasury sanctioned (31 May, 1918), a provisional subsidy of £5 per ton of spelter produced, approximately 3,500 tons per month, for three months while the inquiry was being held.[1] The result of the inquiry was a recommendation that the Ministry of Munitions should take the output of the smelting companies at £56 per ton,and should supply the smelting companies with approximately 5,000 tons of zinc concentrates per month at £11 4s. 9d. per ton. These concentrates cost the Government £10 5s. 0d. per ton, and in order to allow of shipment the Materials Department were willing to forego tonnage allocated to copper and lead from Australia. The price of £56 per ton was arrived at on the basis of a monthly importation of 3,500 tons of Australian concentrates and 9,500 tons of other ores at prices enumerated in a sliding scale agreed to by the producers and the Ministry. Under this arrangement, the Ministry was to refund the smelters the difference paid above the scale prices, and on the other hand, was to have the benefit of any lower prices. The price of spelter, under this plan, would be £60 10s. 0d. per ton, as against the existing price of £63 per ton. With an increase in shipment of Australian concentrates the price of spelter would automatically fall, so that if spelter were produced entirely from Australian ores the price would be reduced to £53 8s. 0d. per ton. From a commercial point of view it was desirable to supply the smelters' requirements entirely from Australian concentrates, which would reduce the price in spelter, and limit the outlay by the Government. As the concentrates had already been paid for by the Government, the additional outlay for the 5,000 tons of spelter which could be recovered from 13,000 tons of Australian concentrates would only be £121,000, all of which would remain in England, whereas, if 5,000 tons of spelter per month had to be purchased in America, it would mean an outlay of £242,000 per month, all of which would remain in America.

It was further recommended that an agreement on these lines should be made with the smelters to the end of the year, thereafter subject to three months' notice on either side. On 3 July, Treasury sanction was given to this scheme.[2]

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[1] D.D.G.M. 702. [2] C.R.V./Gen./2170.

The Ministry did not give notice to terminate their contract when the Armistice was signed, as owing to the high cost of freight the withdrawal of the bonus would have meant the closing down of the smelting industry, which was impolitic in view of the fact that the Ministry still had 60,000 tons of the Australian concentrates, bought in 1916, unsmelted, and that the Board of Trade had contracts for concentrates running over a term of years. Notice of termination of the Ministry contracts with the smelters was given on 4 May, 1919.[1]

XIV. Variation of Australian Contracts in 1917.

The contract for the purchase of 100,000 tons of zinc concentrates annually for ten years, from January, 1918, contained a reciprocal clause, and under it the producers in September, 1917, gave notice that, subject to the approval of the Imperial Government, they proposed to accept an offer received from Japanese smelters for the purchase of about 190,000 tons of concentrates for delivery over 4 years at a flat price of £4 10s. per ton.[2]

The Japanese offer was so much below the Ministry contract price (£9 19s. 9d. at the then price of spelter, £50), that, had it been accepted, a heavy loss must have been incurred by the Imperial Government, and English smelters placed at a great disadvantage.

A committee appointed to consider the position reported as follows :—(27 September, 1917).[3]

> "There can be no question that the contract under the circumstances which have already arisen, and which are likely to prevail for a considerable period after the war, is an onerous one for H.M. Government, and seems to threaten a considerable loss. [Making a minimum allowance for homeward freight and charges] the price payable per ton of concentrates with spelter at £50 will amount to £13 13s. 6d. per ton c.i.f. U.K., or with spelter at £30 per ton it would be £9 5s. 4d. per ton, which prices are beyond the reach of smelters on any economic basis..... We should, in our opinion, take our stand firmly on the principle of "Reciprocal Preferences," admitted by Clause 15 of the contract, and should aim at holding that we are entitled to better terms than any other buyer, and especially that a sale to the Japanese, with their cheap labour, cannot be countenanced, unless the terms of contract B. are modified to something below those to the Japanese. In this case the latter are obviously seeking to establish an industry with which to capture our trade in brass and galvanised iron in the Eastern markets."

The Committee proposed that an entirely new agreement should be negotiated to take the place of contract B., under which H.M. Government could get the control of the whole exportable surplus of concentrates on much more favourable terms than under the existing contracts. Meanwhile, the Board of Trade officially exercised

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[1] C.R.V./Gen./2170. [2] D.D.G.M. 1420. [3] *Ibid.*

its right under clause 15 (*a*), and refused consent to the proposed agreement with Japan (26 September). After considerable negotiation a new agreement was drafted under which the Imperial Government acquired the surplus production of Australia (after Japanese and other contracts had been filled) for the period of the war and for ten years after, £4 10s. per ton being paid for the first 100,000 tons, and £4 per ton for the next 150,000 tons.[1] This compared with a price of £8 17s. 6d. per ton under contract B., with spelter at £45 per ton. Sir Clarendon Hyde commented on the proposal as follows :—

> "In order to pass from a contract which is commercially unsound in some of its features, it is proposed to pass to a far larger contract on lines which are more sound, which involves less risk per ton, but spread over a much larger tonnage and for a longer period. As a trading proposition it seems a reasonable development in an attempt to extricate oneself from an unsatisfactory situation. It, however, means a large trading operation, necessarily with the usual uncertainties attending trade operations, and it is for the Board of Trade to determine if and how far this trading operation, which may be the precursor of many like operations, should be adopted by H.M. Government."[2]

After negotiation with the Treasury, the new contract was entered into on 9 April, 1918.[3] Under it, the contract dated 23 April, 1917,[4] was cancelled, and H.M. Government contracted to purchase all stocks of concentrates and slimes existing on 31 December, 1917, less reserves of 60,000 tons, at a price of 66s. per ton for concentrates in stacks in Broken Hill, and 61s. 9d. per ton for slimes f.o.b. Port Pirie, and 47s. 9d. per ton in stock at Broken Hill. For current and future production H.M. Government contracted to take during the war, and for ten years from 1 July following the declaration of peace, the whole Australian production of zinc concentrates controlled by the Zinc Producers' Association, less reservations to cover sales already made, Australian requirements, and requirements of the Seaton Carew works of the Sulphide Corporation, this latter being limited to a maximum of 30,000 tons annually.

There was the proviso that the buyer need not take more than (*a*) 250,000 tons annually during the duration of the war, and twelve months after ; (*b*) 300,000 tons annually for four years following the terms in (*a*) ; (*c*) 300,000 tons annually for five years following the terms in (*b*).

The price to be paid under (*a*) was 90s. per ton for concentrates for the first 100,000 tons, 80s. per ton for the next 100,000 tons, and 80s. for the next 50,000 tons ; 61s. 9d. per ton for slimes. In the case of the second 100,000 tons, the price was subject to half the net proceeds realised over the purchase price on re-sale being paid to the producers. For the second period under (*b*) the prices were to be 90s. for concentrates, and 61s. 9d. for slimes, both with half profits on

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[1] For further details, see D.D.G.M. 1420.
[2] *Ibid.*
[3] *Ibid.*
[4] For a copy of this agreement, see C.R. 4583.

re-sale. For the third period (*c*), the price under (*b*) would apply if the average price of G.O.B. spelter quoted on the London market for any six-monthly period should be less than £30 per ton. If, however, the average price of spelter on the London market for any six-monthly period should be £30 or over, then the price and terms of the contract dated 23 April, 1917, would apply to all deliveries during that period.[1]

At the end of 1917, English smelters were being paid £56 per ton for their output of G.O.B. spelter. Under contract C., entered into (23 April, 1917) by the Australian Zinc Producers and the Board of Trade,[2] the Australian producers had to deliver their electrolytic or refined zinc to the Ministry at £57 per ton c.i.f. This price was much below that paid by the Ministry in the market. The producers asked that the contract should be temporarily adjusted, and in support instanced the generous manner in which the Producers' Association had responded to the Government's suggestions on the new zinc concentrates contract. The temporary adjustments suggested were :—

(1) The contract for the year 1918 to be altered in so far as refined zinc was concerned to an f.o.b. Australian port basis instead of c.i.f., as at present ;

(2) The buyers to pay for all refined zinc up to, but not in excess of, 5,000 tons, at the price fixed for G.O.B. to English smelters at their works, plus a premium of £5 ;

(3) A deduction of £2 10s. per ton to be made to reduce the price from a c.i.f. to a f.o.b. basis.

At the request of the Board of Trade the application of the producers was considered by the Advisory Committee.[3] The committee stated in reply that the grounds for a revision of the terms were that shipments could not be made except by an allocation of space by the Director of Overseas Transport, and the principle of taking delivery f.o.b. instead of c.i.f., or making an allowance for an increase of freights had been conceded right and left for almost all commodities. The producers' proposal could be summed up as follows :—

	£	s.	d.
Price paid to English smelters for G.O.B.	56	0	0
Plus	5	0	0
	£61	0	0
Less for freight ..	2	10	0
	£58	10	0

[1] Transport difficulties, the collapse of the world market for spelter after the war, and the increased cost of refining in Great Britain, made it difficult for the Board of Trade to sell the concentrates required under this agreement, and a large stock (which would have been still larger but for the prolonged strike at Broken Hill) accumulated in Australia. In October, 1921, the Board of Trade made arrangements to sell some of this accumulated stock at a loss, in order to enable spelter refining works in Great Britain to resume operations.

[2] For a copy of this contract, see C.R. 4583.

[3] D.D.G.M. 1420 ; C.R. 4583.

This proposal was considered most moderate as assuming freight to be, say, £5 per ton, the cost of the refined spelter landed in this country would be £63 10s. per ton, as compared with the then selling price of the Ministry of £75 per ton, while the cheapest purchase that had been made for some months had been £68 c.i.f. London from Japan. The proposal put forward by the Producers' Association was therefore accepted by the Board of Trade.

XV. Cancellation of Scandinavian Contracts.

Towards the end of 1917 the high cost and risk of transport, and the cessation of the Russian demand made a re-consideration of the Ministry's Scandinavian contracts for fine zinc essential. The contracts should have been completed by the end of the year, but the Ministry still owed 12,000 tons of G.O.B. spelter to the firms, while they owed about 4,500 tons of refined zinc from G.O.B. spelter already delivered to them. The cost of sending spelter to and fro from Scandinavia had risen so considerably since the contracts were made that it was far cheaper to buy refined spelter from America, whence it could be obtained at £15 per ton less than its cost under the Scandinavian contracts. In December, 1917, the works had to close down owing to the failure of the Ministry to deliver G.O.B. spelter. The cancellation of the undelivered balance of these contracts was therefore negotiated, the companies accepting an offer of £63,485 by way of compensation (February, 1918).[1]

XVI. Output of Zinc under Assisted Contracts.

Under their contract, Messrs. Chance & Hunt were advanced £35,000 for the erection of two additional units capable of increasing their output of fine zinc by 1,500 tons per annum. The output was to be supplied to the Ministry at cost price plus £5 per ton, while the product of another furnace was also to be at the disposal of the Government; the capacity of the three units being estimated at a total of 2,250 tons per annum. The firm's process was not very successful. Whilst the output fell far short of the estimate—it was only 323 tons from the three units for the first four months of 1917, instead of 750—there was also great delay on the part of the firm in submitting costs.[2]

From figures submitted in April, 1917, the cost of refined spelter produced from the units erected with Government assistance worked out at approximately £92 10s. per ton as against a price of £79 for the product of the firm's original unit, while Messrs. Brunner Mond and Company in the same month offered refined spelter to the Ministry at £72 10s. per ton. On 30 April, 1917, Messrs. Chance & Hunt were notified that, owing to the high cost of production from the two units which had been put up with Government aid, the Ministry did not require any further stocks.[3]

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[1] (Printed) *Weekly Report*, No. 129, IV A (9/2/18). [2] 94/Z./31.
[3] 94/Z./186.

The output of the New Delaville Company also fell short of the estimate of 880 tons per month.[1] In July, 1915, prior to the Ministry contract, the output was 739 tons per month. By the following December output had fallen to 650 tons; over 1916 it averaged 570 tons; over 1917 still lower at 460 tons and for 1918 the average monthly output was only 318 tons. In this case, however, lack of labour and inability to obtain the residuals from which the firm had made their spelter before the war were the main causes of the decreased production.

The quantity of metal dealt with by the department up to and including 30 April, 1919, aggregated 271,000 tons made up as follows :—

G.O.B. Spelter.	Tons.
Bought of English Contractors	99,078
Bought in America	82,158
Bought in Japan	100
Total ..	181,336

Refined Spelter.	Tons.
Bought of English Contractors	10,750
Bought from Scandinavia	24,022
Bought in America	36,237
Bought in Canada	13,682
Bought in Australia (ex. 1918 contract) ..	5,376
Total ..	90,067

The sterling value was approximately £9,000,000 for G.O.B. and £8,000,000 for refined spelter.

[1] C.R.V./Gen./2153.

CHAPTER IV.

BRASS.

I. Introduction.

Brass, which is a copper-zinc alloy approximating 60 per cent. copper and 40 per cent. zinc (generally known in the trade as Muntz metal) possesses plastic or forging qualities at a "cherry-red" heat, and is utilised for munitions production in the manufacture of fuses, cartridge cases, primers and friction tubes. The brass rod supplied to munitions manufacturers is obtained by rolling or by extrusion. By the latter process, a billet or slag of cast metal is forced through a die under hydraulic pressure after being treated to the requisite temperature and the rod so extruded may be either round, square, or any other section according to the die. The composition of the metal used for extrusion purposes can be varied in order to obtain metals of varying qualities: the copper percentage may fall as low as 55 per cent. in rods of low grade, and small percentages of metals such as tin, manganese and aluminium are introduced to obtain metals with high mechanical qualities, while an appreciable percentage of lead is generally introduced to render the metal of good "cutting quality"—*i.e.*, to enable it to be machined on the lathe.

This process of manufacturing brass rods was in vogue in the United Kingdom prior to the war, but the manufacture was confined to a few firms. The plant required was made principally in Germany, and most of the presses in use in this country were manufactured by Krupps. Production of rod by this process was much cheaper than by the old process of rolling, and the rods were of a better texture for machining. By special appliances a "tube" may also be extruded and there is scope for great development in this direction.

During the war, this method of manufacture was developed in England by the Ministry of Munitions, suitable plants for the process being made by Messrs. Feilding & Platt, of Gloucester, Messrs. Davey Bros., of Sheffield, Messrs. Henry Berry, Ltd., of Leeds, and Messrs. Armstrong, Whitworth & Company, Newcastle. A certain amount of machinery was also obtained from America, and the total output of the plants erected by the end of 1917 aggregated approximately 2,000 tons of rod per week. This capacity is greatly in excess of normal consumption before the war, and unless new channels of usefulness are found for the extrusion of "special sections" which might, with advantage, replace a large part of brass casting work, a great deal of the plant is bound to become useless for post-war trade. Such articles as frames, brackets, etc., made from extruded brass sections will be cheaper, neater and cleaner than similar articles cast in sand.

During the war, brass stampings for munitions work were made by the process of "hot forging," which was formerly practically a German monopoly, the billet of brass being heated to a red heat and forged under a drop hammer or power press by means of sheet dies of the required shape. The billet can be cast, or preferably cut from extruded rod, and it is possible to obtain forgings or pressings of quite intricate designs by this method. During the period of the war, great use was made of this process for munition purposes, and in peace time it is likely to be utilised extensively for the making of motor accessories and all kinds of small fittings.

Die-casting, which consists of running the metal in a molten condition under pressure into a sheet mould or die, has not been applied with success to brass. The difficulty of getting a sound casting is thought to be due to the fact that the melting point of brass is considerably higher than that of any other metal which is successfully used for die casting.

II. The Position in May, 1915.

Reviewing the position in May, 1915, Sir Percy Girouard pointed out that no difficulty need be anticipated in obtaining sufficient copper for the 22,500 tons of brass rod and the 22,514 tons of cartridge metal which would be required for munitions production from May to December, but that there would be a shortage of high-grade spelter of 99·9 per cent. purity. He gave the following figures :—

———	Estimated Requirements May-Dec. 1915.	In Stock.	Orders in America.	Balance to be provided.
	Tons.	Tons.	Tons.	Tons.
Brass rod or bar ..	22,500	2,131	2,660	17,709
Cartridge metal ..	22,514	3,082	5,291	14,141

To manufacture the quantity of brass rod and cartridge metal the spelter requirements would be :—

———		Total Requirement of Spelter.	Stock in United Kingdom.	Ordered in United Kingdom.	Ordered in America.
		Tons.	Tons.	Tons.	Tons.
Brass rod ..	5,903	10,617	4,809	2,101	9,766
Cartridge metal	4,714				

These figures showed a surplus balance of 6,059 tons of spelter, but Sir Percy Girouard struck a warning note, pointing out that if spelter of 99·9 per cent. purity was insisted upon for all brass rod or cartridge metal and Admiralty brass tubes, it appeared doubtful whether there would be sufficient metal of this degree of purity. If, however, in the specification for brass rod and bar, and the Admiralty

brass tubes, the quality of spelter could be reduced to what was known as "brass special," *i.e.*, of purity of from 99·25 per cent. to 99·5 per cent. quality, there appeared to be no doubt that there would be sufficient high-grade spelter (*i.e.*, of 99·9 per cent. quality) to manufacture all the cartridge metal that might be required. But this statement included only requirements for British war purposes and did not take into account demands upon the metal for the Allies, and the ordinary trade requirements of neutrals. The report of the Restriction of Enemy Supplies Committee, issued about the same date, pointed out that the requirements of the Allies from America alone would be approximately, 80,000 tons of fine zinc (99·9 per cent. purity), while American production was only estimated at 50,000 tons for 1915.

The War Office specification that all rod for fuses was to be made out of refined spelter was due to the fact that in normal times it was necessary to store fuses; this made it essential that refined zinc should be used, as the small proportion of lead contained in spelter of less purity than 99·9 per cent. caused a "picrate" to form, rendering the fuse practically useless. As a "picrate" took six months to form and the fuse would in all probability be fired long before that time expired, the Raw Materials Department deprecated this use of high grade metal, and recommended that spelter of 99·9 per cent. purity should be reserved for the manufacture of cartridge metal, condenser tubes, and turbine blades for the Admiralty. A great financial saving would result from this change, the difference in cost of G.O.B. or "brass special" spelter and refined spelter being approximately £10 per ton; while it would also allow of the conservation of refined spelter stocks.

This recommendation was accepted. At the same time, manufacturers of brass rod were asked to communicate to the Materials Department of the Ministry the exact position of their contracts for brass bar and rod, to give particulars of their stocks and purchases of refined spelter, and to state their immediate and prospective requirements of G.O.B. spelter. They were further instructed that their stocks of refined spelter would be transferred to the Ministry, and that G.O.B. spelter would be supplied to them at £106 per ton, a like sum per ton being credited to them for all refined spelter transferred to the Ministry.

III. First Efforts to Increase Supply.

The pre-war manufacture of brass rod and bar in the United Kingdom approximated 15,000 tons per annum and, during the first year of the war, no official steps were taken to increase output, all requirements in excess being purchased from America. In the early part of June, 1915, brass rod makers had complained that they were unable to fulfil their contracts for rods owing to the scarcity of spelter, and larger orders for brass rod had to be given both by the Ministry and by Messrs. J. P. Morgan & Company, in America, at a much higher price than was paid to English manufacturers, the difference in some cases being as much as £50 per ton. Mr. Llewelyn therefore urged (5 July, 1915) that British makers of brass rod should be encouraged to erect additional

works, even if capital had to be provided by the Government for the purpose. With few exceptions firms expressed their inability to increase production before the end of the year. Six firms, however, promised an increase aggregating 85 tons per week. At a conference at the Ministry, on 19 July, brass manufacturers were asked (a) whether they could increase their output without interfering with present supplies for arsenals and other purposes, and if so, by how much; (b) whether it would be possible for the makers to form themselves into an association working on the same lines as the Copper and Brass Tube Associations. The makers thought there would be little difficulty in increasing output by 50 per cent., provided the release from the Colours of casters and other experienced labour could be obtained, and in order to meet the views of the Ministry and of the Admiralty, decided to form an Association for war purposes only.[1]

The home brass rod manufacturers were then producing approximately 700 tons per week as against requirements of 2,000 tons a week. Further, it was found that the rod manufactured in England was unsuitable for use on the American automatic lathes which were being installed in great numbers, so that, apart from obtaining a sufficiency of supplies, there was the difficulty of getting rod of suitable quality and finish. Since brass rod firms were greatly limited in their output through shortage of labour, steps were taken to obtain the release of essential men from the Colours, and to encourage the firms to train unskilled labour. This had the desired effect, and the output at the end of six months rose to over 1,000 tons a week, while the quality was much improved by the adoption of new methods, rod being supplied which cut as freely and was as straight and true as American rod.

At the same time, the efforts of the Ministry were directed to the installation of new plant estimated to produce 340 tons a week. Rolling capacity for about 100 tons a week was obtained in South Wales, and arrangements made for the installation of eight new brass presses for extruding rod. The department also encouraged the use of forgings for fuse bodies and shell bushes. These forgings, which were made from bars cast in iron chills, supplemented the output of the rolling mills. They were found to be economical in material and easy to machine: moreover, it was found possible to make use of a large percentage of scrap in casting the bars. Production of forgings at the end of 1916 was at the rate of 300 tons a week.[2]

IV. Utilisation of Scrap.

The shortage of raw material caused the question of the utilisation of a larger amount of brass scrap to be seriously considered in the latter part of 1915. The French Government had been purchasing brass turnings and brass scrap in this country, and at an international conference on metals (24, 25 and 26 November, 1915), the French delegates

[1] Sir L. Llewelyn's Papers, 30.

[2] Hist. Rec./R./1840/7.

requested that France should receive supplies of this scrap through the agency of the British Ministry. Old cartridge cases were being returned from France and were pressed down and remelted, afterwards being used for making brass bar and rod. Brass scrap from turnings, etc., could also be remelted and, with a small addition of virgin metal—copper and spelter—be rolled into cartridge strip. It was suggested that as France was greatly in need of scrap, an economy could be effected if the French Government took over all used cartridge cases in France instead of forwarding them to England and then re-shipping them back again to France. Since, at the end of 1915, approximately 1,500 tons of brass rod was being machined weekly in this country (1,000 tons of English manufacture and 500 tons of imported rod), 750 tons per week of turnings and scrap should have been available, but actual returns from manufacturers only showed between 500 and 600 tons. Home brass works and foundries absorbed 300 tons per week of this scrap, and the maximum available for export was therefore 2/300 tons per week. Against this weekly surplus, the Commission Internationale de Ravitaillement had, between September and December, 1916, applied for and been granted export licences by the War Trade Department for 6,863 tons. There were also applications for licences aggregating 3,895 tons.[1] It was arranged that France should be supplied with 200 tons weekly.

The case for the control of brass scrap by the Ministry was put by Mr. Atkinson, a brass founder and member of the Birmingham Munitions Committee, who showed that the bulk of brass swarf produced was being sold at an average price of £45 per ton, and practically the whole of it was exported to France, while the Ministry was purchasing new brass for munition work at the then price of £125 per ton. Basing his proposals on the experience of the Birmingham Munitions Committee, which was dealing with the swarf produced by its sub-contractors, Mr. Atkinson suggested that the Ministry of Munitions should make it a condition in all brass contracts that the swarf should remain the property of the Ministry, that an organisation should be created to collect swarf and distribute it to smelters in the various munitions areas, who should be allowed £10 a ton for smelting the swarf into ingots, an additional £10 a ton for casting it into strip or bar, while for casting from ingots into say, 2-in. bars, parting off into required lengths, and stamping into, say fuses, £30 per ton should be allowed. Mr. Atkinson assured the Department that these payments were ample and allowed a substantial profit to the smelters, while the works capacity in this country was capable of dealing with all swarf produced.[2] He produced figures showing a saving of £61 per ton over existing Ministry contracts for stampings, and, as about 4,000 tons of swarf monthly could be recovered and dealt with, there would be a monthly saving of £240,000.

Part of Mr. Atkinson's recommendations were at once adopted and in all subsequent contracts for home production a clause was inserted stipulating that all swarf, scrap, etc., resulting from the

[1] Sir L. Llewelyn's Papers, 30. [2] *Ibid.*

manufacture of the rod should become the property of the Government, and would be paid for at a rate to be fixed. The general control of swarf and scrap was postponed until the following year. A Brass and Copper Swarf Section was instituted in March, 1916, and a circular order issued which prohibited metal merchants, who were then forcing up prices, from dealing in scrap metals, and instructed consumers to purchase through the Ministry of Munitions only at a fixed price per ton. The Order also prohibited export except by permission of the Ministry.

The effect of these restrictions was to stop all speculation, and it enabled consumers to purchase at a lower figure. Metal merchants had been selling to France and also to English consumers at £70 per ton; the Ministry purchased the scrap at £56 per ton and sold at £65 per ton. This action not only protected the consumer and assured him of his metal at a lower figure, but incidentally earned a profit of £9 per ton for the Ministry. French requirements of about 100 tons per week were sold to them at cost price, this being a saving to them of £14 per ton or £1,400 per week. Before the end of 1916 the turnover of scrap approximated 1,000 tons per week, showing a weekly profit to the Government of £9,000.[1]

V. Increasing Demands for Brass Rod, 1916-1917.

The demand for brass rod increased rapidly, keeping pace with the growth in the gun ammunition programmes. The first programme, which was forwarded to the Raw Materials Department in July, 1915,[2] covering a period of seventeen months—from August, 1915, to 31 December, 1916—called for a total of 72,979 tons. This covered the gun ammunition orders placed, or to be placed, by the Ministry of Munitions, and did not include metal for orders already placed by the War Office or Admiralty. The programme called for:—

	August–September, 1915. 2 months.		October–December, 1915. 3 months.	
	Home Orders.	Total Orders.	Home Orders.	Total Orders.
	Tons.	Tons.	Tons.	Tons.
18–pdr. cartridge cases	769	769	2,737	2,737
4·5-in. howitzer cartridge cases ..	344	508	907	1,230
No. 100 graze fuse for all H.E. shell from 18–pdr. upwards ..	450	450	1,623	1,648
Total ..	1,563	1,727	5,267	5,615

[1] HIST. REC./R./1840/7. [2] Sir L. Llewelyn's Papers, 30.

With the increased ammunition programmes for 1916 requirements increased fourfold, the figures being :—

	1st Quarter.		2nd Quarter.		3rd Quarter.		4th Quarter.	
	Home Orders.	Total Orders.	Home Orders.	Total Orders.	Home Orders.	Total Orders.	Home Orders.	Total Orders.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
18-pdr. cartridge cases ..	3,745	3,745	6,975	6,975	6,975	6,975	6,975	6,975
4·5-in. howitzer cartridge cases	1,629	2,080	2,610	2,610	2,900	3,572	2,900	3,572
No. 100 fuses for H.E. shell	3,043	3,280	6,128	6,827	7,192	8,438	8,180	9,965
Totals ..	8,417	9,105	15,713	16,412	17,067	18,985	18,055	20,512

This statement gave a total of 65,000 tons as requirements for 1916, but the demand grew rapidly. On 14 January, 1916, Mr. Llewelyn stated that the works organised by his department were producing approximately 1,000 tons a week.

> " We understand," he wrote " that the total quantity required is approximately 2,000 tons a week, but we have no definite information. . . . . It would be very helpful if we could obtain the actual output of Woolwich and other Government works and armament firms who are producing this class of material to enable us to gauge the quantity that will have to be supplied from new sources."[1]

At about the same time a further programme for 1916 was drafted, which showed requirements estimated at 104,000 tons. Supplies from English brass rollers would amount to 52,000 tons, and 20,800 tons had been ordered in America, leaving a balance of 31,200 tons to be provided.

By August, 1916, demand was outrunning supply, owing principally to the very rapid increase in fuse production which had taken place. In order to supply the brass rod required for home contracts and for the fuse contracts placed in Switzerland and France, Messrs. J. P. Morgan were asked to buy, in America, 26,000 long tons for delivery between December, 1916, and March, 1917, of which 10,000 tons were for French and Swiss contracts and 16,000 tons for home requirements. On 14 September, an estimated shortage of 24,000 tons of brass rod for fuse manufacture over the next six months was reported.

Sir Glynn West thought that the immediate shell and ammunition programme could be met, but that an additional quantity from America for the early months of 1917 should be obtained. He strongly advocated the establishment of national factories for the production of brass castings and stampings for fuses, a more economical method of manufacture than the making of fuses from extruded rod. Factories for this purpose could be laid down in existing buildings on economical lines as regarded labour, handling, etc., and dilution by woman labour could be largely adopted. No difficulty was anticipated in obtaining the necessary stamping plant and furnaces; production should

[1] Sir L. Llewelyn's Papers, 30.

commence in about three months and capacity might be provided up to 4,000 tons, half the Ministry requirements. There was also the possibility of production at the Government Rolling Mills, then in course of erection at Southampton.

The Minister was asked (15 September) to sanction the purchase of further supplies of brass rod in the United States, and the arrangements necessary for the production of a large proportion of the requirements in this country at the government factory at Southampton, and a new government factory. So far as Southampton was concerned, the question was one of plant only on a moderate scale, and without adding to existing buildings. It was hoped also that the second factory could be set up in existing buildings to be rented or acquired for that purpose. Production at these factories would mean a great financial saving as well as less dependence upon the United States, except for raw materials. The Minister sanctioned the recommendation relating to the factories, but in view of the probability of an early increase in home production as indicated, decided that it was not desirable to commit the Ministry to a larger purchase in the United States than 10,000 tons of rod for delivery in 1917.[1]

It should be noted that up to this time, practically all fuses had been manufactured either from rolled or extruded rod. When working out the scheme for increasing home production it had been frankly recognised that no appreciable increase in the output of fuses could be hoped for if the fuses had to be made from rolled or extruded rod, owing to the limited capacity of the factories for the work. Moreover, it had been found that fuse stampings made from remelted swarf were equally satisfactory. Instead of having the cast metal rolled or extruded, it was cut into suitable lengths for the stamping presses—thus eliminating the process of making the rod. This effected a saving not only of money but of time, which was even more important. Mr. Denby, of the Elliott Metal Company, Birmingham, who had rendered great service to the Ministry during the negotiations with the brass makers, was invited to act as technical consultant, and on his advice a representative with technical assistance was appointed to represent the Ministry in the Birmingham area.

VI. Organisation of the Brass Section.

It was not until the close of 1916 that a Brass Section was set up in the Materials Department. Prior to its formation, all matters relating to the metal had been dealt with by the director and staff of the Spelter Section, owing to the close relationship of that metal to the manufacture of brass. The increasing shortage of brass made the establishment of a separate Brass Section desirable.

The position was complicated by divided control of semi-manufactured non-ferrous metals; two departments—A.M.2 and E.M.2[2]—were controlling the same manufacturing firms. This dual control,

[1] (Printed) *Weekly Report*, No. 60, IV. (23/9/16).

[2] The Raw Materials Department and the Small Arms Ammunition Branch of Deputy Director-General (E)'s division respectively.

which originated when the Small Arms Ammunition Department was formed, did not conduce to efficiency, and militated against increased production. It had been arranged that small arms firms who were self-contained, *i.e.*, those who cast their own brass and rolled their own strip, should be handed over by A.M.2 to the Small Arms Ammunition Branch, and that when firms controlled by the latter required cartridge strip in excess of their own manufacture, the strip should be obtained from A.M.2. Subsequently this arrangement was modified, and E.M.2 made their own arrangements with all rollers of brass strip for small arms ammunition.

In October, 1916, the Minister decided that the Raw Materials Department must accept responsibility for the supply of all raw materials required by the Ministry, and it thus became necessary that A.M.2 and E.M.2 should agree to a common policy.[1] At a conference on 13 October, 1916, it was decided that the correct line of demarcation for division of control would be to make Deputy Director-General (E) responsible for the casting and rolling of all small arms ammunition and Q.F. strip, while the Materials Department would be responsible for all cast, rolled, or extruded rod, wire, and other semi-manufactured non-ferrous metals. Deputy Director-General (E) was to apply to the Materials Department for all such Raw Materials as had to be supplied by the Ministry, and for scrap. Under the terms of this arrangement the responsibility for the supply of Q.F. strip was transferred from the Materials Department to Deputy Director-General (E). A special section of the Materials Department, under Lieut.-Colonel J. Carmichael, was set up to deal with supplies of rod from America, home production of rod and of stampings and castings.

The duties of the new section were :—

1. To obtain and supply in the required quantities, brass rod, rolled and extruded, brass wire, stampings, castings, billets, and other rolled sectional brass materials, necessary for the manufacture of fuses, primers, and shell components, for home Government manufacture, Swiss contractors, and as required by the Allies ;

2. To arrange for and distribute supplementary supplies from America ;

3. To administer the brass and copper scrap control Orders in such a manner as to ensure all scrap arising from manufacture in the United Kingdom being utilised in work of national importance, and, so far as possible, to confine its consumption to the locality from which it originated, thus obviating unnecessary railway transport ;

4. To see that firms requiring brass material for work not connected with the war were not allowed supplies.

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[1] A.M.2/707.

VII. Increased Production of Stampings.

Meanwhile, steps had been taken to find factories where stamping plant and furnaces could be quickly installed without interference to other munition work carried on there. Eminently suitable were the works of the Carron Company, Falkirk, and of Messrs. Robert MacLaren & Company, Glasgow, while arrangements were also made with the Carriage and Wagon Department of the Midland Railway Company at Derby to install plant. Contracts were also entered into with other firms. Among the orders placed were two for 150,000 stampings of No. 101 fuse weekly from Messrs. MacLaren, and 10,000 stampings of No. 106 fuse weekly from the Crittall Manufacturing Company. Under the former contract the Ministry paid for the cost and the erection of the plant, which was to remain the property of the Ministry on the termination of the war.

In October, 1916, programme requirements for brass stampings for No. 101 and No. 106 fuses for home factories, and for fuse contracts placed in France and Switzerland, amounted approximately to 1,000,000 per week, deliveries to the Continent being estimated at 200,000 a week. Promised deliveries by contractors in the United Kingdom were :—

1916	
October	400,000 per week.
November	663,000 ,, ,,
December	1,004,000 ,, ,,
1917	
January	1,400,000 ,, ,,

French and Swiss production capacity was 400,000 No. 101 fuses weekly, but, owing to short deliveries of stampings by home contractors, together with difficulties which impeded the transport of stampings from England, and of brass rod from America, the output was much in arrears. At the same time orders were being placed for the 106 fuse.

On 14 October, Sir Glynn West wrote :—

> "The position of brass supply to Switzerland is most unsatisfactory. Although, it appears, arrangements have been made for this supply, the necessary stampings are not forthcoming and a serious shortage is threatened.[1] What can be done? The matter is most urgent."

The shipping shortage and transport congestion in America, together with the submarine menace, made American shipments of rod irregular, while at home factories had to be turned over and organised before any appreciable output of stampings could be obtained. During the months of August and September the average weekly shippings of all stampings to the Continent were 132,000. The home production of stampings for the month of October was estimated at 600,000 per week, of which 200,000 had been earmarked for the Continent, while 700 tons of rod—sufficient for 300,000 fuses—were being shipped from America. At the end of October, 400,000 stampings were ready for shipment, but they were held up by the Admiralty owing to the activity of enemy submarines in the Channel.

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[1] C.S.M. 28450.

By November the crisis was over, for although programme requirements were not fully provided for until the end of the year, there was a rapidly expanding output of stampings which relieved all anxiety. The output for the week ending 4 November was 497,000, for the week ending 16 December it was 861,000, while two months later the average weekly output was 1,050,000, and this had risen by the end of June, 1917, to a weekly average output of 1,500,000, despite the fact that shipments of rod from America were nearly 5,000 tons in arrears.

VIII. The Control of Brass and Brass Scrap.

The control of copper, spelter and brass was decided upon at a conference on 19 December, 1916.[1] Under existing arrangements about 75 per cent. of the fuse contractors came to the Ministry for their brass, while others bought brass themselves in the open market. This system of partial control made it impossible for the Ministry to know the extent of its commitments or how the rest of the British brass output was being utilised. In order to overcome this difficulty it was arranged that an order should be issued giving the Ministry complete control of all copper and spelter purchases, whether from home or foreign sources, and that the Ministry should assume control of sales by brass makers and take over the issuing of the necessary certificates, making proper allowance for the carrying of reasonable stocks. At the same time a committee was appointed to advise as to the organisation necessary to secure the effective collection, use and control of brass scrap and copper turnings.

Brass scrap was produced on such an enormous scale in munitions manufacture that the control of it was a very important question. The weekly figures of brass requirements for the gun ammunition programme of 1917 were as follows :—

	Material required.	Finished weight.	Scrap and Swarf produced.
	Tons.	Tons.	Tons.
Fuses	3,100	1,473	1,627
Primers	258	94	164
Tubes, friction and V.S.P. ..	71	40	31
Nose bushes	372	196	176
Fuse sockets	276	145	131
Shrapnel tubes	92	77	15
Total	4,169	2,025	2,144

Over 50 per cent. of the raw material thus became swarf in the machining. In addition there was the swarf from O.F. cartridge strip and the swarf that might be made available from the rod used for the French and Swiss fuse contracts. The total swarf available for remelting and stamping was estimated at over 2,700 tons weekly.

IX. The Reduction of Demand in 1917 and 1918.

In December, 1916, the requirements of brass for the first half of 1917, were estimated at 151,470 tons, and, though orders had been placed in America for 41,000 tons of rod, there remained a deficit of 33,770 tons. The following figures show the position :—

Requirements.	Tons.	Supplies.	Tons.
Aircraft	890	British Output :—	
Gun ammunition	139,000	Rod (1200 tons x 26) ..	31,200
Machine tools	2,580	Stampings (1600 tons x 26)	41,600
Post Office	210	Castings (150 tons x 26) ..	3,900
Railways (Military)	1,215	American orders	41,000
Railways (U.K.)	900		
Trench warfare	4,385		
War Office contracts ..	1,890		
Small arms	400		
Total ..	151,470		117,700
		Deficit ..	33,770

The Minister was therefore asked to sanction the purchase of 40,000 tons of brass rod in America, or alternatively 20,000 tons of brass rod and an equivalent amount of copper and spelter.[1]

During the latter part of 1917, the benefit of the steps which had been taken to increase home production began to be felt. "The position is satisfactory" wrote the Director of Materials in November . . . . "Our chief concern now is not the lack of supplies, but how to reduce our demands on manufacturers in such a way as to cause the least dislocation of labour, and to keep works going with sufficient orders, so that in the event of larger requirements being called for in the future we shall be able to meet them." [2]

The home demand on the department for the last quarter of 1917 was for 1,465 tons of brass rod weekly, a total of 19,045 tons. In addition, the department was required to carry a stock of five weeks' supplies—roughly 7,500 tons—making a total of 26,545 tons. Supplies were more than equal to this demand

	Tons.
Supplies from America due for delivery ..	6,500
Supplies from home manufacturers (averaging 1,200 tons per week)	15,600
Stocks in store	11,000
Total ..	33,100

The production of stampings had also overtaken requirements, and large stocks had been got together. "Here again" wrote the Director, "we are reducing orders for manufacture so as to cause as little inconvenience to plant and labour as possible, and to keep stocks within reasonable limits."

[1] C.R. 4355. [2] Sir L. Llewelyn's Papers, 30.

At this time the output of fuse body stampings in the United Kingdom had risen to 1,750,000 per week, and the Ministry was in a position to offer to supply France with brass rod and fuse body stampings (6 October, 1917).

The following table summarises the position :—

Type of Stampings.	Deliveries to Consumers. Average of 4 previous weeks.	Total Deliveries by Producers. During two weeks ending 28 December.	Approximate Stocks.
Fuse Body No. 80 Mark VI.	56,631	65,072	168,300
Fuse Body No. 80 Mark VII.	116,318	96,140	3,320,000
Fuse Body No. 83	6,800	29,000	175,000
Fuse Body No. 101	2,200	55,652	2,518,000
Fuse Body No. 106	167,052	335,368	5,284,000
Fuse Cap No. 80	2,500	66,000	707,270
Base Plug No. 80	—	—	120,000
Fuse Cap No. 101	93,662	150,000	2,862,000
Sockets 18-pdr.	38,255	37,810	458,860
Sockets 60-pdr.	—	—	128,716
Nose Bushes	19,104	22,790	157,559
Extrusion Billets	52 Tons	225½ Tons	1,582 Tons

Reductions in the demand for primers and friction tubes during 1918 also disturbed calculations. The manufacturing programme for primers was approximately 1,300,000 pieces per week at the end of 1917, and production at this rate was forecasted in a programme, submitted in September, 1917, to the Materials Department to continue for the first two quarters of 1918. This programme was, approximately, adhered to for the first quarter of 1918, but was reduced to 800,000 a week for the second three months ; it was further reduced to 200,000 a week for the third quarter, and in October to 50,000 a week. The metal required for 1,300,000 primers represented a consumption of 350 tons of rod, and supplies were arranged for by the Raw Materials Department on this basis. The maximum actual demand was 250 tons and, owing to the rapid reduction of demand, heavy stocks, representing 300 weeks' requirements, were left over at the Admiralty.[1]

The forecast of requirements of friction tubes was 500,000 a week for the last quarter of 1917, 400,000 weekly for the first three months of 1918, and 300,000 weekly for the second quarter. With practically no notice to the Materials Department contracts were entirely stopped towards the end of the second quarter. Demands rarely reached programme figures, and with the sudden cessation of manufacture, stocks for which there was no demand were left.

The stocks on 31 October, 1918, amounted to 3,000 tons of primer metal and 465 tons of friction tube metal. For the manufacture of primers, rod of 1·7/16 in. diameter was principally used, and for the friction tubes a special mixture of 70/30. The metal was useless for ordinary trade or munition purposes, and as it appeared that no further manufacture would be required, the surplus stocks were written down and put into consumption at scrap value (£75 per ton).

[1] D.D.G.M. 1206.

X. Reduction of Prices.

The Raw Materials Department was able to secure a substantial reduction of prices. In March, 1915, the Contracts Branch of the War Office had contracted for the Ordnance Factories' requirements of cartridge strip at a price which showed that the cost of manufacture, exclusive of materials, was £33 per ton, but in July, 1915, though there had been an increase in the cost of coal, and higher wages were being paid, the Raw Materials Department, after negotiation with the newly-formed Brass Makers' Association, proposed to place contracts for the Ordnance Factories at a reduced price of £30 per ton. On 23 September, however, the Minister asked the Director of Materials, "Is there any reason to think that the price which is being paid is more than we fairly ought to pay for Rolled Brass strip? . . . . If there is any reason to think there is anything in the nature of a ring being formed, will you tell me what evidence you have to this effect?"[1]

In view of information received from Woolwich as to costs of manufacture, the Contracts Department stated that the price of £30 per ton was excessive, and that they were not prepared to sign the contract, but as supplies were urgently needed, they eventually agreed to the price of £30, with the insertion of the words, "subject to revision." After a discussion with the Brass Makers' Association, Mr. Lever arranged that the contract should stand for two months, and that during that period the question of costs should be gone into, by the examination of books, but, in December, the Secretary of the Association informed the Ministry that "members decline to submit books to Mr. Lever's examination at any time." The Director of Materials pointed out that before the contract was placed with the Brass Makers' Association, he was guided by the prices arranged by the Contracts Branch at an earlier stage, and he thought that it was fallacious to take Woolwich as a guide without a careful examination of their books. A Munitions Committee had estimated that, including provision for overhead charges, etc., the casting alone cost £9 18s. 6d. per ton for howitzer metal case, which was £3 7s. 5d. per ton in excess of the cost set out by Woolwich for casting the same metal. These differences with the Brass Makers' Association required tactful handling, for the Ministry at that time was entirely dependent upon them for urgent requirements, and for the last two months of 1915 deliveries of metal did not reach expectations, although the output for the previous four months had been most satisfactory. It should be noticed that brass makers had strong reasons for resisting an attempt to cut down their prices, as they were able to sell their output to armament firms and munition contractors at much higher prices than the contract price allowed by the Ministry.

The action of the Contracts Department, however, bore fruit, inasmuch as it led the Materials Department to institute inquiries in other directions, with the result that Messrs. John Lysaght, Newport, offered to put down plant at their own expense to make 200 tons of

[1] M.W. 49854.

strip per week for 4·5-in. and 18-pdrs. at £20 per ton, delivered at Woolwich, or at cost price, plus 10 per cent. profit, whichever was the greater sum. This offer was accepted, and similar arrangements were also made with other firms. The Brass Makers' Association then put forward a reduced list of prices which the various makers were prepared to accept upon a six months' contract, and under pressure from the Ministry the same prices were accepted for one-month contracts.

By agreement with the Brass Rod Association, the prices of brass rod were arranged upon a sliding scale, based on the market quotations for electro-copper and G.O.B. spelter. This scale provided a manufacturing charge of £19 6s. 9d. per ton for rods, including loss of metal in manufacturing, the contractors being left free to buy their own copper and spelter in the open market. Later, as the result of an investigation into the books of the manufacturers by the Costs Accounting Department of the Ministry, the manufacturers agreed to a manufacturing charge of £14 per ton, plus a melting loss of 3 per cent., which, calculated on a 60/40 mixture, was equivalent to another £3 per ton. The investigation of manufacturers' books therefore, resulted in a saving of £2 per ton, but the Costs Accounting Branch were also desirous of excluding "hidden profits" obtained by contractors who bought scrap and swarf—the latter at £65 a ton—from the Ministry for conversion into rod. To deal with this difficulty they proposed to introduce an agreement which practically involved the free issue of all materials, a suggestion which the Raw Materials Department strongly opposed (March, 1917). Ultimately it was agreed that the Ministry should charge up all metal at virgin metal price and pay the contractor a price per ton on his deliveries, based on the virgin metal price plus cost of manufacture. Periodically, the manufacturer was to charge the Ministry with the waste, calculated on a fixed percentage of the scrap and swarf supplied to him, *i.e.*, 7½ per cent. for scrap, and 20 per cent. for swarf.

XI. The Government Rolling Mill at Southampton.[1]

In February, 1916, requirements of small arms ammunition were 400,000,000 rounds per month, equal to 2,210 tons of brass strip per week.[2] In the same month Mr. Lloyd George authorised an increase to 500,000,000 per month, and on 5 April a further increase to 550,000,000 rounds per month, this being equivalent to a weekly requirement of 3,000 tons of brass strip.

The productive capacity of the United Kingdom was approximately 1,000 tons of brass strip per week in February, 1916, and, by April, 1916, arrangements had been made to increase this by 300 tons per week. To meet programme demands without foreign aid it was essential that additional productive capacity should be created, and in February, 1916, it was proposed that a Government Rolling Mill should be erected at Southampton, and this was agreed to by the Minister in March.

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[1] See also Vol. XI, Part VI, Chap. VIII. [2] HIST. REC./R./1840/11.

The factory was only intended to deal with the requirements of the increased programmes, and was designed as a complete unit to produce an output, working night and day, of :—

Brass strip	.. ..	3,750 tons per month.
Cupro-nickel strip	..	1,000 ,, ,, ,,
Brass and cupro-nickel cups		42,000,000 per week each.

The estimated cost of construction of the Government Rolling Mill was £680,000, and financial sanction was granted for that amount ; in addition, Treasury sanction was also given for the expenditure of £80,000 for items not included in the original estimate.

With the installation of the necessary plant it was estimated that an additional 4,000 tons per month of brass could be cast and worked up, namely, 2,000 tons of fuse stampings, and 2,000 tons of Q.F. (cartridge case) strip. The cost of the plant for stampings was estimated at £30,000, and for the strip at £15,000, and if the strip was disced at the factory ready for pressing, an extra cost of £8,000 would be involved. If this last operation was carried out at the factory, there would be a saving of 40 per cent. in scrap, which could immediately be made use of, thus saving loss of metal, carriage, and deterioration of scrap. As the factory was fitted out on modern lines, with all known labour-saving devices, a very considerable saving over the costs in ordinary factories was anticipated. Sanction to proceed with the scheme was given on 4 October, 1916, the Ministry agreeing that it was " a most valuable and promising proposal."

Including £50,000 for the land, the erection of the factory cost £1,240,000, part of the excess over the original estimate being accounted for by the construction of plants for making fuse stampings and Q.F. cartridge discs. It was estimated that the mill would begin manufacture in October, 1916 ; it actually commenced cupping operations in November 1916, rolling operations on 30 January, 1917, and casting on 7 February. But owing to a greatly increased production by the trade, which by the end of 1917 amounted to 2,000 tons of brass strip and 500 tons of cupro-nickel strip per week, and subsequently to reduced programmes, it was never possible to give the mill sufficient work to keep it running at its fullest capacity. The maximum output produced in any one week was :—

Brass strip	441 tons
Cupro-nickel strip	64 tons
Brass cups	24,000,000
Cupro-nickel cups	19,250,000

Early in 1918, programme demands for small arms ammunition were reduced to 900 tons of brass strip per week and 225 tons of cupro-nickel strip. This was approximately only one-third of the country's capacity and the question arose as to the best method of obtaining the reduced requirements with the least hardship to the trade and labour and with the most economical results to the Government.

The Director of the Small Arms Ammunition Department proposed that Woolwich Arsenal and the Government Cartridge Factories, 2 and 4, should be closed down and that the cartridges required should be

obtained from Messrs. Kynoch, the Birmingham Metal and Munitions Company, and the King's Norton Company, using their own strip supplemented by a sub-contract with the Elliott Metal Company, and Government Cartridge Factories, 1 and 3, and Messrs. Greenwood and Batley, who were all to be supplied with cups from the Government Rolling Mill. This proposal meant the closing down of all strip producers, excepting two of the Government Cartridge Factories, the Elliott Metal Company and the Government Mill at Southampton.

The Raw Materials Department opposed this suggestion on the ground that production by the trade was more economical, while the difference in quality was only slightly in favour of the Government Rolling Mills. The trade charge for strip was £17 per ton, but the firms returned to the Government at least £5 per ton in excess profits and £1 per ton in income tax, rates, taxes, etc., while they saved the Government £1 per ton by partially financing themselves. Further, owing to geographical position, an additional £1 per ton was saved the Government in transport of material. The net cost of trade production was, therefore, approximately £9 per ton, certainly not more than £10 per ton.

In comparison, the lowest cost at the Government Rolling Mill was £16 per ton, and even if the mill was run to its full capacity to produce all the strip required, the cost, it was contended, would not fall below £14 per ton. "No stretch of imagination can suggest figures which can make the Government Rolling Mill anything but substantially dearer than the trade."

While accepting the statement of the Director of Small Arms Ammunition, that the Government Rolling Mills produced a strip which made a cup equal to the very best produced by the trade, and therefore, perhaps slightly above the average of the trade, the reduced requirements would of necessity mean the closing down of the least efficient trade mills. Any difference in quality only implied some very small increase in the percentage of rejections, and could not outweigh the big difference in the price of strip. The Materials Department, therefore, recommended that the Government Rolling Mill should be closed down, and if possible devoted to other work, and the trade allowed to supply the requirements under the reduced programme. An allocation to the trade was proposed which would allow of a weekly production of 924 tons with a reserve production of 526 tons. This involved the closing down of about 20 mills, which in the opinion of the advisers were the least efficient. A similar procedure was proposed with regard to cupro-nickel strip production.

In supporting the proposals of the Raw Materials Department, Sir Ernest Moir expressed the opinion that even were the cost of strip supplied by the trade equal to the Southampton cost, which it was not, he would, on general lines of policy favour the keeping of the trade going, in preference to a Government factory.

The Labour Department being asked by Sir Ernest Moir to consider the effect of these proposals favoured the closing down of the Government Rolling Mill at Southampton, in preference to the trade factories in the Birmingham district. At the Government Rolling Mill 1,426

people (907 men and 519 women) were, on an average, engaged on productive work. The men were regarded by the Labour Supply Department in the light of "mobile labour," for which there was a great demand in other centres. The women were recruited locally from shop assistants and domestic servants, and the Labour Department felt that no great hardships would be felt if they returned to their former occupations. On the other hand, it was undesirable to create more unemployment in the Birmingham area, where the reduction of the ammunition programme alone would have serious effect on employment, as it was in this district that the finished cartridge was produced. Subsequently, the Birmingham strip manufacturers intimated their willingness to accept £15 per ton for brass strip, this price being subject to excess profits duty and income tax.

When placing the matter before the Minister, the Financial Secretary, Sir L. Worthington Evans, summarised the situation as follows :—

"(1) *Labour.*—I consider that the balance is in favour of employing the Midland firms.

(2) *Economy.*—I consider that the balance is in favour of employing the most efficient of the Midland firms.

(3) *Safety Margin.*—Capacity for increased production should be maintained.

(4) *Southampton Mills.*—May be used for other purposes—a special inquiry should be directed into its possible uses."

Mr. Churchill remitted the question to the Munitions Council (14 March), which, on 22 March, 1918, agreed[1] that a case had been made out for the closing of the Government Rolling Mills at Southampton, but that no steps should be taken until the supply of strip on favourable terms for the future had been assured. In order to secure this, the Contracts Department in association with Council Member M., and the Small Arms Ammunition Department was instructed to negotiate with the larger and more efficient firms in the cupro-nickel and brass strip trade, and agree with them about a price for a term sufficient to cover the remaining period of the war.

This decision was taken at a time which coincided with the German offensive against the British Fifth and other Armies, and, as a result, the reduction on the small arms ammunition programme was suspended.[2] During a fortnight's fighting approximately 350,000,000 rounds of small arms ammunition had been expended, or captured by the enemy, and it was necessary to increase output to 250,000,000 per month, as against the reduced programme of 150,000,000. All demands upon the department for strip were met and a reserve stock was maintained in conformity with programme requirements at about 6,000 tons per month.

During 1918 costs of production at Southampton were reduced by the introduction of a bonus on output, the use of labour-saving devices and the saving of material, and by the date of the Armistice brass strip costs had fallen to between £11 and £12 per ton.

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[1] HIST. REC./R./200/43. [2] D.M.R.S. 135B.

CHAPTER V.

ALUMINIUM AND CRYOLITE.

I. Introduction.

Aluminium was chiefly used before the war for electrical conductors, in metallurgical processes for welding or casting iron or steel, in various alloys with a tensile breaking strain of from 13 to 41 tons per square inch, in castings for motor-car and aeroplane engine parts, in explosives, such as ammonal, and for making various utensils for domestic use. The war brought a large demand for aluminium for munitions purposes in connection with the manufacture of fuses, hand grenades and incendiary bombs, ammonal explosives, motor transport and aviation.

The basis of aluminium is bauxite, mined chiefly in France, Austria, America and Canada, which is calcined to free it from moisture, and further treated to precipitate the alumina from which aluminium is produced.

Aluminium is manufactured in America, France, Switzerland (for Germany), Great Britain, Canada, Austria, and, to a smaller extent, in Italy, the world's production of aluminium in 1913 being as follows :—

	Tons.	Percentage of World's Production.
United States of America	29,500	37·5
France	15,000	19·0
Switzerland and Austria	15,000	19·0
United Kingdom	10,000	12·7
Canada	5,900	7·5
Norway	2,500	3·2
Italy	800	1·1
Total ..	78,700	

On the formation of the Ministry of Munitions there was little of the metal available for early delivery, floating stocks were small, and a considerable rise in price was anticipated. France's requirements equalled her production, in addition to which she had to fill certain Russian contracts. Switzerland's production was largely controlled by German interests, so that there was little hope of securing supplies from this source. Italy's production approximated 1,000 tons per annum and was not sufficient to meet her demands for war purposes. It appeared, therefore, that apart from British production, America was the only source of increased supplies.

There were two producing companies in great Britain and one in Canada. The British Aluminium Company had works in Scotland, at Kinlochleven and Foyers, Inverness-shire, at Vigeland, Norway and Strangfjord, near Bergen, Norway, which gave an annual output of

10,000 tons of ingots, about 30 per cent. of which was produced by the Norwegian factories. With an increased water supply for electrical power the output of the Scottish factories could be increased by 800 to 1,000 tons per annum. There was also the Aluminium Corporation of North Wales, which was expected to have an output of about 600 tons a year. The Northern Aluminium Company of Canada, controlled by the Aluminium Company of America, produced about 10,000 tons a year, of which approximately 7,000 tons were available for export.[1]

Returns obtained from munition manufacturers in May, 1915, showed that their requirements to the end of the year were covered by stocks and purchases, but the additional orders placed by the War Office and the Ministry meant an increased demand for the metal.

II. Position in June, 1915.

The position in June, 1915, so far as could be ascertained, was as follows :—

Requirements.	Tons per month.	Supplies.	Tons per month.
Fuses	720	British Aluminium Company.	830
High explosives	412	Aluminium Corporation.	50
Hand grenades	220	Northern Aluminium Company.	640
Motor transport	250		
Aviation purposes	25		
Waterbottles and mess tins ..	27		
Total ..	1654	Total	1520

In addition, aluminium was required in the manufacture of steel, the amount varying from 2 oz. to 1 lb. per ton. In certain cases ferro-silicon could be used as an alternative, but for steel castings and steels for special armament purposes, the use of aluminium was absolutely essential. In 1913 the output of steel for all purposes was about 7,700,000 tons, averaging 4 oz. of aluminium per ton, which meant a consumption of approximately 900 tons of aluminium yearly. There was thus at this early stage a considerable shortage, which could only be made up from supplies outside the United Kingdom and Canada.[2]

Prices were rising rapidly. In August, 1914, aluminium was sold at about £80 per ton. In the following January, after slight fluctuations, it was fairly steady at £81 to £83 per ton. By the end of April, 1915, the demand for the metal had carried the price to £97, and it reached £100 by the end of May. Within a month it had jumped from £122 to £140, and by the end of August, 1915, was £180 to £200, with a prospect of reaching £300 or £400 per ton.

The whole position was discussed at a series of conferences at the Ministry with representatives of the British Aluminium Company and the Northern Aluminium Company. The trade was hostile to the proposed control of aluminium, as they thought it would prevent them

[1] Sir L. Llewelyn's Papers 1. [2] *Ibid.*

from competing with Germany and America on equal terms after the war, but on the advice of the Raw Materials Department, which was of opinion that aluminium firms were holding up supplies with a view to increasing the price (29 July, 1915), the two British manufacturing companies, the British Aluminium Company and the Aluminium Corporation, Ltd., were placed on the list of controlled firms, as from 18 August, 1915.[1]

The possibility of substituting some other metal or alloy for aluminium in the manufacture of steel, thus effecting a yearly saving of approximately 1,000 tons, was enquired into, but was negatived on the advice of Sir Robert Hadfield, who thought it indispensable to the manufacture of sound steel. Other possible economies were the substitution of some other metal in motor-car work, and in the production of grenades and fuses.

There was considerable difficulty in increasing the production of aluminium. The best bauxite deposits were in France, where most of the miners were serving in the army; there were also large deposits in America, but these were controlled by the American Aluminium Company, which also obtained supplies from France and was all-powerful in the trade, controlling the Northern Aluminium Company of Canada. Mr. A. V. Davis, the president of the American Aluminium Company, had unlimited capital, unlimited water power and a controlled market.

III. Centralisation of Purchases.

In order to reduce competition it was thought advisable that all Government purchases of aluminium should be made through the Raw Materials Department, and the War Office, Lord Moulton's Committee on High Explosives, the Trench Warfare Department and the Admiralty were requested to refrain from making any enquiries for or purchases of aluminium, bauxite, cryolite, hydrate of alumina, or petroleum coke except through the Raw Materials Department (27 August).[2]

Meanwhile, as enquiries in the market on behalf of Russia, France, Belgium and Italy were tending to raise the price of aluminium still higher, it was thought desirable to ask that these Allies should refrain from going into the market, and should not make any enquiries for aluminium except through the Ministry of Munitions (19 August, 1915).

At a conference with M. Thomas and other representatives of the French Ministry (6 October, 1915), the possibility of obtaining aluminium from France, in spite of the decline in production, which had fallen from 15,000 to 5,000 tons per annum, was discussed. The Aluminium Française Company had promised delivery of 150 tons per month up to a total of 700 tons in return for the release of 700 tons of metal consigned by them to Russia and detained in British ports. The 700 tons was released for return to France, and the British Ministry asked that the Aluminium Française should continue delivery of 150 tons per month as the metal was urgently required, contractors for

[1] C.R. 1444; Sir L. Llewelyn's Papers, 1. [2] Sir L. Llewellyn's Papers, I.

ammonal being held up for lack of it.[1] M. Thomas stated that his requirements were 600 tons per month, which he was experiencing difficulty in getting, but as soon as the Aluminium Française had the 700 tons of metal released by the British Government, they would be able, instead of keeping the Norwegian supply for the French Government, to send it to England at the rate of 150 tons per month. The first consignment was ready and a regular supply of 150 tons per month would be arranged.

A little earlier a stock of aluminium, owned by Messrs. H. R. Merton & Company, had been commandeered, as the firm asked too high a price for it (20 September, 1915).

In a statement of 24 September, supplies, against estimated requirements for 1916 of approximately 23,668 tons,were shown as follows :—

	Tons.
British Aluminium Company	9,960
Aluminium Corporation	600
Northern Aluminium Company and Aluminium Company of America	4,000
Total ..	14,560

Against the deficit of 9,108 tons, there were purchases from :—

	Tons.
Japan	553
Prize Court	448
Messrs. H. R. Merton	460
Messrs. E. T. White	13
Total ..	1,474

Purchases in prospect totalled 6,020 tons, and included a parcel of 750 tons from Messrs. Merton, and 5,000 tons from French sources. Even then there was a prospective deficit of 1,614 tons, to which was added the demand of the Russian Government for 9,000 tons and lesser demands on account of other Allies.

The only possibility of meeting this deficit was by purchases from the Aluminium Company of America, who, however, were stated to be oversold.[2]

IV. Aluminium from America and Canada.

In 1915, about half the world's output of aluminium was manufactured in America, and of this from 50,000 to 60,000 tons were produced from plants in the United States by the Aluminium Company of America, and the remaining 10,000 to 12,500 tons from the Shawinigan Falls plant of the Northern Aluminium Company of Canada, which was subsidiary to and controlled by the Aluminium Company of America.

[1] HIST. REC./R./1011/3. [2] Sir L. Llewelyn's Papers,1.

Prior to the war a considerable quantity of aluminium was exported from Europe to the United States, equivalent to about 40 per cent. of the total American consumption. The war cut off this supply, and American output had now to make good the deficiency and to meet the heavy new demands arising from the manufacture of munitions. The Raw Materials Department of the Ministry of Munitions endeavoured to arrange for the reservation of the whole output of the Canadian plant (estimated at 10,000 tons annually) for the purposes of the British Government, at £140 per ton, subject to the proviso that a proportion not exceeding 25 per cent. might be retained for the manufacture of munitions in Canada. An undertaking to this effect was given by the London representative of the Northern Aluminium Company (3 September), but was almost immediately withdrawn on his being informed from the company's headquarters (6 September) that a large proportion of their output for 1916 had already been sold, mainly to manufacturers of fuses in the United States.[1] Mr. D. A. Thomas (later Lord Rhondda), who was then in America on a special mission, was asked to deal with this difficult situation (10 September). On his request the Canadian Government prohibited all exportation of aluminium from Canada, except to the United Kingdom, and it was arranged that the Customs Department were to consult Mr. Thomas before letting any consignments through to the United States. Mr. Thomas hoped by this means to secure for munitions purposes at least 7,500 tons per annum, including the quantities already booked by British munitions firms. Moreover, the prohibition of export formed a valuable counter in negotiating with Mr. Arthur Davis, who was president both of the American and Canadian companies. It transpired that the entire output of his American plants was already earmarked for commercial purposes, and that he was depending entirely on the output of the Canadian plant to supply the needs of munitions manufacturers, both in Canada and the United States. He had, indeed, already sold over 7,000 tons from the Canadian plant to manufacturers of Russian and Japanese fuses, and of fuses No. 80 and 80/44 for the Canadian Government. These sales were not made direct to the manufacturers, but through the Aluminium Castings Company, who were said to be paying the Northern Aluminium Company a price nearly double that arranged between the latter company and the British Government, and also to have expended large sums on the establishment of plant for the manufacture of aluminium fuse parts.

In these circumstances Mr. Davis represented that he could not fairly be expected to cancel the sales already made to the Aluminium Castings Company, or to disappoint the manufacturers of Russian, Japanese, and English fuses, who were dependent upon him for supplies. After a number of conferences, however, he submitted a proposal to guarantee the supply of 5,000 tons annually from the Canadian plant, and of a further 3,000 tons in 1916, and 4,000 tons annually thereafter from his plants in the United States on certain

[1] Hist. Rec./R./1141/5.

conditions, which included a guarantee of a sufficiently long contract to enable him to arrange for the equipment and erection of a new plant in the United States. The development of an independent source of supply of aluminium in Canada or in the United States was virtually out of the question, as apart from the difficulty of obtaining developed water power, the necessary supplies of alumina could not be secured except from the Aluminium Company of America. It was, therefore, necessary to accept the best terms obtainable from Mr. Davis, and his readiness to assist the British Government was recognised. After lengthy negotiations with Mr. Davis, a contract was arranged, and on 30 December, Messrs. Morgan cabled that they had closed with the Northern Aluminium Company for 7,500 tons (2,240 lbs.) of ingots of 98/99 per cent. purity for delivery in equal monthly quantities during 1916 at 30 cents per lb. (£144 per ton), f.o.b. The contract was subject to the following conditions :—

(1) Aluminium would be subject to inspection by representatives of the buyers, but if inspection were waived the seller's certificates as to weights and compliance of the aluminium with specifications would be accepted, on the understanding that such acceptance should not be deemed to relieve the seller of his obligation to make good any deficiency found to exist on arrival of the aluminium in England, but this should not be construed to mean that the seller assumed responsibility for delivery after the aluminium had been loaded on board cars at the respective points of shipment.

(2) The Northern Aluminium Company would be permitted to export aluminium from Canada provided they furnished the usual guarantee that such exported material would not reach the enemies of England.

(3) The Northern Aluminium Company would be permitted to supply to the British Aluminium Company the quantity required by the latter for the manufacture of fuses and other munitions of war, subject to the approval of the Ministry of Munitions.

(4) The British Admiralty would, on or before 1 February, 1916, lease to a British company to be formed by the Northern Aluminium Company the bauxite rights in British Guiana which had been the subject of negotiations with the Northern Aluminium Company.

(5) The terms of payment would be cash upon presentation of shipping documents and the certificates of the inspectors of the buyer or of the seller, as the case might be.

The purchase represented a saving of £645,000 on the London market price of £230 per ton, and £1,245,000 on the American price of £310 per ton.[1]

[1] (Printed) *Weekly Report*, No. 22, I. (25/12/15).

The contract concluded with Mr. Davis enabled the department to produce a satisfactory balance sheet for 1916.[1] Against requirements estimated at 23,688 tons, the department had made the following purchases :—

	Tons.	Price per ton.	Cost per ton.
		£	£ s. d.
British Aluminium Company ..	9,600	140	140 0 0
Aluminium Corporation	600	Gran. at 200	150 0 0
Northern Aluminium Company ..	7,500	144	150 0 0
Norway	3,700	158	160 10 0
Japan (in stock)	281	—	201 0 0
Stocks in hand	1,330	148	150 0 0
Total ..	23,011		

Average cost per ton, £148 2s. 7d.

In addition to the purchases negotiated during 1915, a contract was entered into with Mr. A. V. Davis on June 5, 1916, for 12,000 short tons at 35 cents per lb., equivalent to 10,714 long tons at £164 15s. 6d. per ton.[2]. During the same month the department purchased 2,000 tons for the Russians at a price of £306 per ton, and in the following month paid £292 per ton for parcels for its own account. Thus the contract with Mr. Davis meant a saving to the British Government of £1,360,000. The total purchases made and prices paid by the department to 31 July, 1916, were :—

1915		Tons.	Price. £ s. d.
September ..	British Aluminium Company (output say)	10,000	140 0 0
December ..	Northern Aluminium Company of Canada	7,500	141 9 4
	Det Norske Nirstze (Norwegian Works of L'Aluminium Française) ..	3,445	160 10 0
1916			
June	Aluminium Company of America ..	10,714	164 15 6
July	Aluminium Castings Company, Ohio ..	1,000	292 7 4
	Total ..	32,659	

Average cost per ton, £150 8s. 0d.

Purchased on Russian Account.

1916		Tons.	Price. £ s. d.
February ..	Aluminium Company of America ..	2,634	259 7 2
June	Bremer Waltz Corporation	89	285 6 0
		2,009	306 10 4
	Total ..	4,732	

[1] Sir L. Llewelyn's Papers, 1A. [2] A.M.2/538.

V. Economies in the Use of Aluminium.

In November, 1915, the sanction of the Chief Inspector, Woolwich, was obtained for the substitution of brass for aluminium in No. 80 fuse,[1] which materially relieved the aluminium position, as 5,040 tons of aluminium were allocated to the manufacture of this fuse in Europe, in addition to 2,500 tons for manufacture in America. There was a shortage of brass rod also, but a largely increased production of rod had been arranged for,[2] while there was little prospect of relief in the aluminium situation for some years. This change over was only effected at an increased cost of 1s. 2d. per fuse, as appears from the following comparison :—

	Brass.	Aluminium.
Weight in lbs.	1·521	0·494
Price of metal per lb.	1s. 3d.	1s. 4·607d.
Cost of metal used	1s. 10·8d.	8·2d.
Difference in favour of Aluminium	—	1s. 2·6d.

The programme then in operation called for 289,000 No. 80 fuses per week, and the extra cost amounted to £17,500 per week or over £900,000 per annum. Subsequently programmes were increased, until during 1918 and up to the time of the cessation of hostilities the average weekly output was 500,000 fuses at an increased cost of nearly £2,000,000 per annum, as compared with aluminium.

Economy in the use of the metal in the motor trade industry was also possible. From returns sent in by manufacturers utilising aluminium for motor and general trade purposes, it was found that the amount of metal required by them was 1,583 tons a month, or 19,000 tons a year,[3] while it was estimated that the amount of metal required by the War Department for lorries, ambulances, etc., was at the rate of 7,662 tons a year.

The possibility of using a substitute for aluminium in the manufacture of cars, lorries, etc., was discussed at a meeting with the trade on 28 November,[4] and the trade promised its full co-operation in effecting economies. In consequence there was some friction between the Ministry and the War Office, as the Director of Motor Transport complained that the action of the Ministry involved an interference in the relations between the War Office and the contractors who were providing motor transport for that Department and delay to urgent War Office orders.[5] The Ministry insisted on its right to control materials and to decide cases of relative priority, but it was arranged that a representative of the War Office should be present when priority questions affecting the War Office were decided.[6] At the same time the attention of the Trench Warfare and Explosives Departments was drawn to the fact that a serious shortage of aluminium was threatened

[1] (Printed) *Weekly Report*, No. 15, I. (16/11/15).
[2] See above, Chap. IV.
[3] Sir L. Llewelyns' Papers, 1A.
[4] *Ibid.*
[5] D.D.G.B. 12.
[6] Q.M.G.3/92/4592.

during 1916, and that it was therefore essential to curtail its use by substitution or otherwise (12 November, 1915). They were asked to re-examine all specifications calling for aluminium, bearing in mind that it was " most desirable that the minimum quantity of aluminium should only be allowed in present and future specifications."

VI. Schemes to Increase Output.

The possibility of increasing home production came before the Department in the autumn of 1915, various schemes being put forward by the British Aluminium Company, and the Aluminium Corporation, Limited.

The former company had in course of erection certain extensions to their factory at Burntisland, Fifeshire, for the purification of bauxite into alumina, but an increased production of aluminium in this country by the company could only be obtained by the creation of an additional water supply for the company's works at Kinlochleven, Argyllshire, at a cost of about £100,000. Pipe tracks had been installed, together with power plant and furnaces, and the output value of the proposed additional water supply was estimated at 1,000 tons of metal per annum. The water supply would have to be drawn from a private lake. Negotiations with the owner had hitherto been fruitless, but the company urged that by the exercise of pressure from the Government the negotiations might be brought to a satisfactory conclusion forthwith without the necessity for Parliamentary procedure. The company asked the Government to advance the £100,000 required at 4½ per cent.

A second scheme suggested by the company, which depended on the diversion of water from Loch Ossien, was estimated at a cost of £110,000, and would secure, it was thought, another 1,000 tons of aluminium per annum. The Government was asked to advance the capital on the same terms as in the former scheme. Both schemes were submitted to the Finance Department and approved, £200,000 debentures being given as security. The additional alumina required for these schemes was to be produced by an extension which the British Aluminium Company were making at their own expense at their Burntisland works.[1]

VII. Supplies to the Allies.

Early in 1916 General Hermonius appealed to the Ministry of Munitions for a loan of 1,000 tons of aluminium to meet Russian needs, pointing out the extreme urgency and military importance of aluminium requirements, and under the pressing circumstances, the Ministry granted the loan and a consignment of 150 tons on account was immediately shipped.[2]

In February, 1916, the Ministry purchased in America, on Russian account, 3,150 tons of aluminium ingots at £231 10s. per ton of 2,000lbs., the total amount of the purchase being £729,382. The metal had

[1] The schemes put forward by the British Aluminium Corporation were on a smaller scale and were not recommended for adoption.

[2] Sir L. Llewelyn's Papers, 300.

previously been offered to the Russian Commission in the United States at 60 cents per lb., or £282 10s. per ton, and the Ministry purchase represented a saving of £66,000. The Raw Materials Department was also able to buy on Russian behalf in America, 1,900 tons of discarded aluminium power transmission cable which could be cut up, remelted, and used for the production of munitions of war. This was purchased at a cost of approximately £536,000, and the metal proved of considerable military value to Russia.

Subsequently it came to the knowledge of the department that Russian demands were being duplicated to the French Ministry of Munitions, and in order to obtain a reliable estimate of Russian requirements, and the degrees to which Great Britain and France should be respectively charged with their provision, a conference of Allied representatives, presided over by M. Albert Thomas, was held in Paris (6 and 7 April, 1916). Colonel Ignatieff, the Russian representative, agreed that the demands should not have been sent to both France and England, but owing to their urgency the demands had been communicated to the Russian committee in London, and at the same time they were sent to Paris, it being understood that the Paris committee should inform the London committee of the quantities of material delivered. This, however, had not been done.[1]

The conference decided that the Russian demand, 17,000 tons to July, 1917, could be reduced by a better utilisation of supplies and a stricter economy of resources, and Colonel Ignatieff agreed that Russian requirements to July, 1917, could be met with 14,150 tons. England undertook to provide 4,150 tons, including 3,150 tons which had already been bought from the United States, and 1,000 tons which had already been lent by her to Russia. She would do her best to supply Russia by means of purchases in the United States with 2,000 additional tons before 1 October, 1916. France undertook to provide the balance of 8,000 tons from her Norwegian and other sources of supply.

Owing to increased programmes, difficulties arose in 1917 with regard to supplies. Russian representatives, accompanied by members of the Commission Internationale de Ravitaillement and the Inter-Allied Munitions Bureau, conferred with the Director of Materials before submitting the Russian materials demand to an Inter-Allied conference (16 February, 1917). The Russians asked for 4,560 tons of aluminium from England for the first six months of 1917, but the Director of Materials pointed out that the British Ministry was short of its requirements of the metal by 15,000 tons, and apart from purchases of 1,465 tons which had been arranged on Russian account, it was not possible to secure any further supplies except at the enhanced figure of £310 to £320 per ton, and for this purchase Treasury sanction would have to be obtained by the Russian Government. On behalf of Russia, it was urged that the Norwegian output had been disappointing; they had anticipated receiving 3,000 tons from this source during 1916, and were relying upon 5,000 tons to 30 June, 1917, but no deliveries had been made to date.

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[1] Notes of Conference at Paris, 6 and 7/4/16. (HIST. REC./R./1800/6.)

At the Allied conference on 6 March, 1917, the Russian demand for 9,000 tons for the second half of 1917, 6,000 tons to be supplied by France and 3,000 tons by Great Britain, was accepted by both the French and British Ministries.[1]

Though Italy's output of aluminium was not sufficient to meet requirements, she was a producer of the metal, and with the erection of proposed new factories, it was anticipated that she would be self-supporting. Meanwhile, her deficiency had to be made up through foreign sources, and to tide over a difficult period in 1916, the British Ministry of Munitions sold the Italian Government 50 tons at £200 per ton, against a market price of £280 per ton, and also lent 55 tons of ingots.[2] Subsequently a request for the purchase by the Department of 500 tons on Italian Government account was complied with (13 and 14 July, 1916) and by the end of July 256 tons had been supplied, the balance being delivered at the rate of 50 to 80 tons per month. From this time onward Italian requirements of the metal were submitted to Inter-Allied conferences, and an allocation made.

At a conference of representatives of the British and French Ministries of Munitions, held in Paris early in 1917, the Director of Materials for the British Ministry complained that the French company owning the Arendall Factory in Norway had not fulfilled their contract to supply 3,500/4,000 tons of aluminium during 1916, an amount of 1,642 tons only having been delivered.[3] It was explained that the company had met with numerous difficulties in extending their plant. Some of these difficulties were due to the British Government, which had delayed furnishing licences for the shipment of copper and graphite to Norway; failed to give a license to the *S.S. Bernado* carrying 3,000 tons of machinery for the new works from America to Norway; and placed an embargo on Danish cryolite, which caused a delay of two months in bringing new smelters into operation. In spite of all these difficulties, which were added to by a general strike and inundations depriving the company of electric power, the company claimed to have delivered 2,037 tons up to 15 January, 1917, the total output for 1916, excepting a small reservation for the use of the company and for sales in Norway, approved by the British Legation in Christiania. The British War Office had been informed of the situation in the autumn of 1916, and advised that every effort should be made to instal a supplementary factory for 1917, as the output of the old works for 1917 was earmarked for the Russian Government.

VIII. Control of Aluminium.

Supplies having been assured by the concluding of the Northern Aluminium Company's contract in December, 1915, steps were immediately taken to exercise control over the metal. The decision was hastened on account of a report from General Long, Director of Military Transport, War Office, that his inspectors had found aluminium

[1] Minutes of Conference, 6/3/17. (Sir L. Llewelyn's Papers, 508.)
[2] Sir L. Llewelyn's Papers, 300.
[3] Minutes of Conference, 20/1/17. (HIST. REC./R./1800/55.)

being used in several workshops for civilians' motor cars.[1] The control of aluminium by the Ministry would have great advantages.[2] It would eliminate middlemen, speculators and commission agents; it would enable the Ministry of Munitions to ensure a distribution of available supplies in the manner best calculated to serve the war purposes of the Government; while it would give the Ministry of Munitions power to enforce upon suppliers and users of aluminium and alumina, conditions which it was unable to insist on, but which had, to some extent, been observed at the request of the Ministry as an act of grace on the part of those concerned; as for example the sale of aluminium in all its forms to the Government, or to Government contractors for munitions of war at certain fixed prices, and its use for munitions of war only unless with the permission of the Ministry of Munitions. The adoption of this policy naturally entailed the taking over of all stocks of holders to whom licences were not granted, the fixing of a selling price, and the establishment of a Ministry organisation for the distribution of the metal purchased and taken into stock by the Ministry.

On 7 December, 1915, aluminium and alumina were placed under Regulation 30a of the Defence of the Realm Act, and on 8 January, 1916, dealers in and users of aluminium and alumina were instructed to forward to the Director of Materials returns of their stocks of aluminium, alumina, aluminium alloys, etc.

A further Order was issued in February, 1917, which extended control to aluminium scrap and swarf. These Orders ensured that all the metal or its constituent alloys were utilised for munitions of war unless a Ministry of Munitions permit had been granted to the user, and that the Department obtained figures of supplies and requirements. Private trade was of necessity interfered with, but manufacturers frankly recognised the position and there was little complaint.

The price at which aluminium was sold to contractors in 1916, was fixed at £155 (5 January, 1916), but the rise in the cost of supplies in the latter part of the year involved the Department in a loss of about £16 8s. 0d. per ton, or £350,681 on the 21,353 tons sold at this price. The average cost of American aluminium was £190 3s. 5d. per ton, and of Norwegian £168 per ton. This loss was reduced by a sum of £84,320, being the difference in the price of the metal sold to Allied Governments.

In order to cover rising prices and recoup this loss, the selling price of aluminium was raised to £225 per ton as from 1 January, 1917, which price was to cover cost of freight and administrative charges, estimated at £10 per ton from America and Norway, or $5\frac{1}{2}$ to $6\frac{1}{4}$ per cent. on the price, which was low in view of the shipping risk, and a margin of $1\frac{1}{2}$ per cent. for losses at sea and other contingencies. The Exchequer and Audit Department, enquiring into the details of these arrangements, asked whether the possibility of reducing the issue price of £225, as suggested by the Assistant Financial Secretary on 10 January, 1917, had been considered. The price of £225 was maintained, however, in

[1] D.D.G.B. 12. [2] Sir L. Llewelyn's Papers, 1A.

order to meet the 1916 loss on account of American prices continuing high,[1] and in view of the fact that an alteration would disturb contractors. The profit made in 1917 was £235,452, which very nearly balanced the loss on 1916, while a real economy was effected by the control of prices. The Controller and Auditor-General criticised this arrangement on the ground that since the increase in price in 1917 was reflected in the price of the finished article, the Ministry did not really recoup its loss,[2] but this argument also applied to the low 1916 price, which kept down the price of the finished articles.

Freight, administrative charges and losses in transit were settled on a common basis for practically all issues by the Ministry to the Allies and Colonies, but in cases such as that of aluminium, where nearly all the material was used for Government work, and where any increase in price was reflected in the price paid for the finished article by the Ministry, the bare outlay only on freight, etc., was added to the purchase price.

IX. Increased Demand for 1917 Programmes.

During 1916, there was an increasing shortage of aluminium and a great rise in price. The aluminium requirements of the Allies for the year 1917 were estimated to amount to nearly 60 per cent. of the world's production, excluding enemy countries and Switzerland, the bulk of whose output was sold to Germany, the balance being absorbed by the Swiss market.

The Allies depended upon the United States and Canada for 41·7 per cent. of their requirements, 34·6 per cent. being produced by England, France and Italy, and 23·7 per cent. by Norway. In January, 1916, the Ministry of Munitions had fixed the price at £155 per ton delivered at the consumers' works, but this was only rendered possible by the fact that the Ministry had been able to enter into favourable contracts for a long period ahead. In the meantime prices in the United States of America, the only open market in the world, continued to rise. Some of the metal had been bought at £306 10s. per ton, and as much as £425 per ton was quoted, while there was no longer any possibility of covering a deficit by purchases in any market other than the United States.

Further economy in use was therefore absolutely essential, and Heads of Departments were asked (17 November, 1916) to impress upon their subordinates the necessity of exercising thought and ingenuity in economising the metal. But before adopting a substitute for aluminium involving substantially increased expenditure on any given munition of war, departments of the Ministry were asked to inform the Director of Materials of the quantity and weight of the aluminium or aluminium alloy thus replaced, and of the proposed substitute. No increased production programme involving the use of aluminium should be launched without first ascertaining from the Director of Materials whether it would be possible to provide the additional quantities of the metal required.

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[1] M.F./E. and A./153 ; M.F./Mats./339. [2] D.F.3/P.A.C./14.

By December, 1916, it had been definitely decided to use granulated aluminium produced from scrap and swarf in the manufacture of thermit, while arrangements were being made to use a proportion of remelted scrap alloy in the construction of motor vehicles.

The Director of Materials also urged that aluminium should be used less extravagantly for smoke-producing mixture in H.E. shells. For this purpose 5,000 tons were asked for in 1917, which would increase the Allied deficit. Again, if the use of aluminium for bullet core tips was discontinued, experiments having shown that a suitable substitute was available, it would mean a saving of approximately 2,600 tons of aluminium per annum. The alarming deficit was threatened for 1917 owing to recent unforeseen demands which had been made on the Department, the latest being an increase from 1,200 tons to 5,765 tons of the metal for the Air Department, and no finality would even then seem to have been reached, for a demand was pending for 4,800 tons of aluminium powder for smoke mixture.[1]

The programmes involving the use of aluminium appeared to be made without first ascertaining whether the metal was available, and the Director recommended that priority arrangements should be instituted, the Air Departments of the Admiralty and War Office to take precedence; then, in order, machine guns, steel makers, motor transport and finally fuses, the use of the metal in the manufacture of high explosives being entirely dispensed with.

The Director emphasised the fact that the use of aluminium powder for explosives was an extravagance, that it was not used by the French Government for this purpose. The proportion of aluminium used in the manufacture of ammonal was extravagant. The specification called for 17 per cent. of granulated aluminium, but this could safely be reduced to between 6 per cent. and 10 per cent. The Explosives Department agreed, and when ammonal was superseded by amatol the use of aluminium for explosives was practically eliminated. The British Ministry was under an obligation to supply Russia with 7,000 tons of aluminium and Italy with 2,000 tons, which it was impossible to supply unless 1917 requirements were covered by additional purchases, or requirements all round were reduced. Russia and Italy should be requested to exercise the strictest economy in the use of aluminium. Within the past month Russia had purchased 700 tons of granulated aluminium and aluminium powder for explosives, whilst Italy was exporting electric fans with aluminium blades to India and the Colonies.

In order to meet the anticipated shortage the Director advised that 10,000 tons of aluminium should be bought in the United States. It was doubtful whether under existing conditions this metal could be bought for 1917 below £310 per ton, but if a proportion of the 1918 requirements were included it was possible that a better bargain might be made. Sir Frederick Black agreed with these recommendations. Strictest economy being enjoined, a system of rationing users was set up, while delegates from the Commission Internationale de Ravitaillement were informed of the position.[2]

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[1] Sir L. Llewelyn's Papers, 1A; D.D.G.M. 087. [2] D.D.G.M. 087.

X. Supplies in 1918.

As a result of the economies insisted on by the Raw Materials Department, and of the close control of aluminium scrap and the system of rationing, the aluminium position greatly improved in the early months of 1917. Economies had been effected in the use of the metal in the manufacture of high explosives, smoke mixture and fuses, and, basing requirements on the then basis of consumption, Great Britain was self-supporting in regard to production of the metal. There was also a reduction, as the result of the Milner Commission, in the quantity allocated to Russia. The aggregate result was that the average monthly consumption was estimated at approximately 1,000 tons, or, at the outside, 7,000 tons for the six months. As against this, consumption, supplies and stocks approximated 19,000 tons, allowing of an estimated surplus at 31 December, 1917, of 12,000 tons.[1] Assuming the war to continue through 1918, the Aluminium Section estimated in May, 1917, that the approximate figures would be :—

Supplies.		Requirements.	
	Tons.		*Tons.*
Stocks on 1 January, 1918 ..	12,000	Great Britain ..	14,000
British production, including Norwegian owned factories ..	12,000	Surplus	10,000
	24,000		

The British Aluminium Company estimated that they would have a surplus production of 2,367 tons, and the company asked that the Government should withdraw some of the restrictions on the general use of aluminium, or purchase their surplus output. The Ministry therefore agreed to the purchase of 2,000 tons at a reasonable price (4 June, 1917).[2]

There was also the output of the Northern Aluminium Company, and if their production of approximately 10,000 tons per annum was again purchased, there would be a surplus of about 20,000 tons.

Such a change in the position had not been foreseen by the department, and the question whether it would not be financially economical to substitute aluminium for brass wherever possible was considered. The relative values of brass and aluminium at the time (June, 1917), taking their respective volume into consideration, were approximately in the ratio of £225 to £360. Aluminium at £225 per ton was a purely fictitious price, and as there was a prospect that the market price for 1918 would be reduced to £180 per ton, or less, it was estimated that the substitution of aluminium for brass would mean a saving of £3,600,000. Indirectly, the turn over from brass would give the Materials Department a lever when negotiating copper purchases in the United States, and would materially assist in regulating the price.

[1] D.D.G.M. 1012. [2] *Ibid.*

As compared with consumption during 1917, requirements for 1918 showed a striking reduction :—

Rationed Supplies for 1917.

	Tons.
Fuses	2,220
Ammunition	660
High Explosives	1,660
Hand Grenades	500
Tanks	260
Machine Guns	1,066
Explosives Works	300
Bombs and Shells	500
Steel Makers	800
Motor Transport	2,250
Admiralty	2,300
Air Department, War Office	5,000
War Office Contracts	288
Smoke Mixture	3,136
Ferro-Tungsten	—
Miscellaneous	500
Total	21,440

Estimated Requirements during 1918.

	Tons.
High Explosives, Hand Grenades and Tanks	2,000
Machine Guns	1,000
Explosives Works	200
Bombs and Shells	60
Steel Makers	400
Motor Transport	2,400
Admiralty	2,000
Air Department, War Office	5,000
War Office Contracts	200
Ferro Tungsten	240
Miscellaneous	500
	14,000

Sir Frederick Black summarised the position as follows :—

"It has always been recognised that Aluminium is by far a more economical metal than brass. One ton is said to go as far as three tons of copper or brass, and therefore, for that purpose, Aluminium up to even as much as £350 or £360 a ton would be as economical as brass. The bearing on the present situation as regards purchase of Aluminium is that if it should be necessary to revert to Aluminium, we must clearly provide a further supply."[1]

An offer had also been received from the Northern Aluminium Company to supply 10,000 tons of metal at 35 cents per lb.—(£165 per ton)—the price of the running contract, but the Director of Materials recommended that, in view of the surplus of 10,000 tons, £100 per ton would be a fair price. (3 July, 1917).[2]

[1] D.D.G.M. 1012. [2] *Ibid.*

Mr. Davis was informed that the British Government would allow him to export bauxite from British Guiana, but in view of the fact that he would then be in a position to manufacture aluminium at a cheaper rate, he was asked to quote a favourable price for British requirements over 1918. This proved an effective counter, Mr. Davis cabling through Messrs. Morgan an offer of 12,000 short tons (10,714 long tons), at a price of 30 cents per lb. or £141 9s. 4d. per ton (28 September, 1917).[1] Treasury sanction, however, was only given for the purchase of 5,000 tons to cover the first half of 1918.

XI. The Fixing of the World Price.

Following the entry of the United States of America into the war, there was a largely increased home demand for aluminium, of which speculators at once took advantage. New plants had been established in the States of New York, Pennsylvania, New Jersey, Maryland, Tennessee and North Carolina, and American production had increased from approximately 44,000 tons in 1915, to 80,000 tons in 1917, sufficient to meet all demands. The increased price was therefore not due to scarcity of metal, and to prevent speculation the War Industries Board of America, in agreement with producers, fixed the maximum base price of aluminium at 32 cents per lb. (£147 per ton), as and from 1 March, 1918. This price was subject to revision after three months, and for the second quarter of 1918 the price was fixed at 33 cents per lb. (£152 per ton). The conditions laid down by the Board were that the producing companies should not reduce the wages then being paid to workers, that aluminium should be sold to the United States Government, to the public in the United States, and to the Allied Governments at the same maximum base price, that producers were to take the necessary measures under the direction of the War Industries Board for the distribution of the metal to prevent it falling into the hands of speculators, and were to exert every effort to keep up production.[2]

XII. Air Ministry Demands in 1918.

The largely increased air programme decided upon in the latter part of 1917 called for 1,300 tons of aluminium per month for the year ending June, 1918, but subsequently this was increased to a minimum of 18,000 tons for the twelve months. This was a tremendous increase, as releases of the metal for the Air Services in the six months ending June, 1917, were 2,995 tons. Though at first sight, after the difficulties experienced in obtaining a sufficiency to cover requirements, it seemed impossible to meet the demand for 18,000 tons, a 200 per cent. increase for one branch alone, yet the supply of about 18,400 tons from August, 1917, to August, 1918, was arranged for.[3] This was due to the great increase in production. In 1915, the world's production was 87,000 tons : it stood at 159,000 tons in 1916, and there was a further increase to 170,000 tons during 1917.

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[1] D.D.G.M. 1012. [2] C.R.V./U./220. [3] A.S.24567/1917.

The supply of aluminium Pitot tubes (of $\frac{5}{16}$-in. to $\frac{3}{8}$-in by 22 wire gauge aluminium tube), required under the 1918 aircraft programme, presented difficulties. The programme called for 150 miles of tube a month, whereas the existing plant in the country was only capable of producing 12 to 15 miles a month. The Air Board appealed to the Raw Materials Department, and obtained the assistance of Mr. A. R. Wyllie, who had been mainly instrumental in building up the brass rod output. Mr. Wyllie enlisted the services of two firms, and after a series of experiments conducted under his supervision, an entirely new process was evolved, the tube being extruded direct from the press, instead of being cast and drawn out, as had been the practice hitherto. By this means the necessary requirements of the Air Board were met, and at a lower cost, the price being reduced by the new process from 12s. 6d. a lb. to 5s. a lb., including the costs of the experimental stage. The monthly saving amounted to 7s. 6d. per lb. on $18\frac{3}{4}$ tons of tubes, a total of £15,750.

XIII. Liquidation of Stocks.

When the Armistice was signed, Ministry stocks and running contracts for aluminium totalled 13,457 tons, of the value, at an average price of £170 per ton, of £2,250,000. The Ministry selling price up to this period was £225 per ton for ingots. This excessive stock was almost entirely due to an overestimate of requirements by the Air Ministry, which had only taken 10,000 tons out of the 18,000 tons asked for from September, 1917, to September, 1918. All control orders were suspended on 24 December, 1918, and the liquidation of stocks was begun.

XIV. The Supply of Cryolite.

For the production of aluminium from bauxite (its main source), natural or synthetic cryolite is used as a flux for adding to the alumina when melting it in the electric furnace.[1] Deposits of natural cryolite in its pure state, *i.e.*, in which alumina and fluor-spar are present in combination, are found in Greenland only,[2] the mines being worked on a long concession from the Danish Government by the Øresund Chemiske Fabriker of Copenhagen. The company refined the raw cryolite and supplied it in a form suitable for use in the manufacture of aluminium.

Synthetic cryolite is an artificial product very similar to refined Greenland cryolite, manufactured from sulphate of alumina and fluor spar, both of which are found in England and also in Germany.[3] Synthetic cryolite is largely made in Germany. British requirements of cryolite were met exclusively by imports from Denmark until 1918, when steps were being taken to produce it synthetically in the United Kingdom.[4]

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[1] Aluminium can be extracted directly from cryolite. The method is, however, expensive, as the aluminium yield (8–12½ per cent.) is small.

[2] The chemical analysis shows: Fluor-spar, 53–54. Alumina, 12–13. Sodium, 32.

[3] Refining is done by the alkali process; its purpose is to eliminate iron and other impurities.

[4] HIST. REC./R./1830/2. *See* also below, p. 88.

Of the Greenland output of the raw mineral, some went direct to North America, but the greater portion was refined by the Øresund Chemiske Fabriker for European and Japanese consumption. The production in 1913 was about 10,000 tons, of which 2,000 tons went to North America, and 8,000 tons to Copenhagen ; in the first year of the war, 1,200 tons were exported thence to Great Britain.

The export of the refined article to Germany and Austria, in which countries it was mostly employed for enamel goods, decreased after the outbreak of the war. A considerable quantity, however, continued to be exported through Germany to Switzerland, where it was used in the manufacture of aluminium, mainly on German account. The decreased exports to Germany were apparently due to the fact that that country was producing artificial cryolite in sufficient quantities,[1] and owing to the decreased export there were, in the early days of the war, considerable stocks of the refined mineral in Copenhagen.

In June, 1915, the Admiralty Committee for the Restriction of Enemy Supplies requested the Foreign Office to ascertain the amount produced in Greenland and its destination,[2] and also whether it was included in the Danish list of prohibited articles. The Board of Trade wished it placed on the contraband list to prevent its import into Germany, but as cryolite was practically a monopoly of Greenland, and was a Danish national industry, the Danish Government was unwilling to agree to prohibit export to Germany.

As a result of the representations of the Committee for the Restriction of Enemy Supplies, the right of search was suddenly and rigorously applied, and two vessels belonging to the Danish Cryolite Company, with cargoes from Greenland, were arrested by British patrols and detained. This action, however, threatened to interrupt the supply of a necessary munitions material, as the Øresund Chemiske Fabrike threatened not to deliver the cryolite due under contract to the British Aluminium Company unless they were allowed free sailing. As a result, the vessels were released.

In the spring of 1916 the cryolite situation once more became critical, as the Admiralty again detained the ships of the Øresund Company and refused to release them until they obtained an assurance that no cryolite refined from their cargoes would be allowed to go to Germany. There was some conflict of interest between the Admiralty and the Ministry of Munitions in this matter. The Ministry urged that though Germany was apparently still importing Greenland cryolite through Denmark, the importation had latterly considerably decreased owing to the synthetic manufacture in the former country, and that it would be impolitic to attempt to obtain total prohibition of export from Denmark (September, 1915). The Foreign Office then suggested a compromise. The cryolite exported by the Øresund Company to Germany was exchanged for soda ash, which was much needed in Denmark, and on 20 May the Foreign Office proposed that in return for certain monthly quantities of soda from the United Kingdom,[3] the

[1] C.R.V./D./13. [2] C.R.V./D./8. [3] C.R.V./D./052, 085.

Danish Government should prohibit export of cryolite from Denmark to Germany. The Danish Government could not accept this proposal, arguing that if Germany's supplies of natural cryolite were cut off she would manufacture a substitute, which would spoil the Danish Company's cryolite business in the future.

The Foreign Office, however, succeeded in negotiating an agreement with the Danish Chamber of Manufacturers, which undertook in return for permission to carry on regulated trade with Germany in cryolite, that no cryolite refined from the cargoes of the two vessels would be allowed to proceed to Germany.[1] Hereupon, the vessels were released. By the terms of this agreement[2] (10 August, 1916), the Øresund Company was to be allowed to sell 33 per cent. of its total sale of pure cryolite to the Central Powers and Switzerland, at a reasonable price based on pre-war standards plus increased expenses. The 33 per cent. of the total cryolite sales was to be equivalent to one half of the total sales to the Allies and countries other than the Central Powers and Switzerland, and if the cryolite sold to the Allies and to Norway did not reach its destination, the amount to be allowed to go to the Central Powers was to be reduced in proportion. Switzerland was to be included in the 33 per cent. allowed to the Central Powers, unless the cryolite were sent thither *viâ* France. The price was subsequently fixed by agreement at £26 5d. per ton, as against the pre-war price of £21 or £22.

The Admiralty were, however, bent upon preventing any cryolite being obtained by Germany, and insisted that the vessels of the Øresund Company should continue to enter a British port for examination. On the urgent representations of that company, the Foreign Office in April, 1917, suggested to the Ministry of Munitions that, as there appeared to be no reason for this stringent regulation, the Director of Overseas Transport should request the Admiralty to waive it.

Meanwhile, the manufacture of artificial cryolite had been commenced in the United Kingdom. In view of the enemy's expressed intention of capturing all vessels proceeding to the United Kingdom with cryolite, the Admiralty strongly emphasised the necessity of pressing forward the manufacture of synthetic cryolite in this country, and of securing, as reserve, as large stocks as possible from Danish sources of the refined cryolite. In December, 1917, the Øresund Company obtained free transport to Greenland of a considerable amount of food, coal and materials (copper wire and rails), in return for cryolite at a cheaper rate.[3]

In January, 1918,[4] the British Aluminium Company was placed in a difficult position by American competition for Greenland cryolite. This meant that the company would receive less than half the quantity

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[1] The Contrabrand Committee considered that, before the release of the cryolite ships, steps should be taken to induce the Øresund Company to sell their existing stock of 4,000 tons of refined cryolite to the British Government under conditions which would prevent any further supplies reaching Germany from that source during the continuance of the war. (Printed) *Weekly Report*, No. 52, IV. (29/7/16).

[2] *Ibid.* No. 61, IV. (30/9/16). [3] C.R.V./D./052. [4] C.R.V./D./085.

supplied in the previous year, and that very late in the season. The Admiralty, on being informed, were of opinion that a general understanding between the Allies should be arrived at as to the supplies of cryolite.[1] Hitherto, cryolite had been exported from Greenland to Copenhagen, and then divided by the British Government between the Allies, but access to Denmark being rendered difficult by submarine warfare, it was not at all certain that they would be able to continue supplies to the Allies.[2] The position was made more difficult by the fact that the dependence of the Allies on Greenland cryolite appeared to be fully realised by the Danish Government, which might put fresh obstacles in the way of direct exports of raw cryolite from Greenland to the United States, with a view to protecting the Danish refining company. The question was considered at the Paris conference of 19–23 February, 1918, and plans for Allied co-operation were arrived at. The Admiralty were still uneasy as to the amount of cryolite received by Germany (15 April, 1918). The Allies were said to be receiving only about 57 per cent. of the Danish exports of raw cryolite, but the Restriction of Enemy Supplies Department stated that the export of cryolite to the enemy by the Øresund Company was less than the amount which the company were entitled to export under the terms of the cryolite agreement.[3] The position was improved by the fact that the British Aluminium Company had meanwhile extended its activities, and had laid down plant for the manufacture of artificial cryolite from which an output of about 1,200 tons per annum was expected.[4]

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[1] C.R.V./D./052. [2] C.R.V./D./085. [3] *Ibid.*
[4] (Printed) *Weekly Report*, No. 147, IV.A (22/6/18).

CHAPTER VI.

LEAD.

I. Introduction.

The position with regard to lead was a difficult one. Up to 1909 the lead market was open, but in that year German interests succeeded in establishing the "Lead Convention," by which they secured to themselves, and, so far as England was concerned, to Messrs. Henry R. Merton & Company, London, practically the whole of the world's production. In this convention were included the Broken Hill Proprietary Company, the American Smelting and Refining Company, the Penarroya Company—a French company owning large works and mines in Spain—besides several of the most important continental producers. The Germans had also obtained control of large lead interests in Mexico, the product of which had hitherto been shipped under contract to England, and had acquired the ownership of important mines and works in Spain. The world's production, therefore, before the war was almost entirely controlled by Germany or German interests.

Production had for some years been practically stationary, and with an annually increasing consumption there was little reserve of the metal. But for the splendid and loyal support of Australia the position of the Allies would have been most serious. The world's production of the metal for 1913 was 1,135,262 tons, of which Australia produced 116,000 tons, Great Britain 30,500 tons, Canada 17,089 tons, and Burma 3,858 tons.

WORLD'S PRODUCTION, 1913–1917.

	1913	1914	1915	1916	1917
Spain	203,000	—	171,472	147,406	173,000
Germany	181,100	—	—	—	—
France	28,000	—	—	—	—
Great Britain ..	30,500	19,684	15,767	12,500	—
Belgium	35,750	—	—	—	—
Italy	21,700	20,464	21,812	24,300	—
Austria	22,312	—	—	—	—
Hungary	1,790	1,368	—	—	—
Greece	18,400	20,684	11,595	9,424	—
Sweden	1,235	1,396	1,918	2,075	—
United States ..	395,398	485,011	487,177	530,000	492,000
Mexico	55,530	28,000	55,000	27,000	—
Canada	17,089	16,487	20,250	18,500	16,036
Japan	3,600	4,563	4,764	11,100	15,000
Australia	116,000	96,000	101,547	136,395	152,399
Burma	3,858	10,548	6,920	11,081	16,964
Total ..	1,135,262	704,205	898,222	929,781	865,399

Imports of pig lead to the United Kingdom for 1913 totalled 204,146 tons, of which 72,252 tons were received from Australia, and 3,064 tons from British India, the remaining two-thirds (140,000 tons) being imported from neutral countries, the chief sources being Spain, the United States, Mexico and Greece. With France and Italy dependent in a great measure upon Spanish lead, it was realised that British supplies from that country would have to be a decreasing factor, while owing to domestic troubles the output of Mexico and Greece could not be reckoned upon with any certainty. No supplies, either, could be looked for from Canada, where the production was insufficient to meet domestic consumption. Outside the British Empire, therefore, the only source of supply that could be relied upon was the United States, and here, with a rapidly expanding home consumption and greatly increased demands from France, Italy and Russia, there was little likelihood of the Ministry securing its requirements except at inflated prices. It was therefore necessary to increase and secure control of production within the Empire.

For the three years preceding the war the output of Australian lead aggregated 335,000 tons. Home consumption averaged approximately 10,000 tons a year, leaving an average of 100,000 tons annually for export. The biggest producers were the Broken Hill Proprietary Company, who were anxious to assist the British Government. The company in 1915 offered to place the whole of their output at the disposal of the British Government, and from May, 1916, their whole production was controlled by the Ministry.[1] Besides this increasing production, the advantageous terms which the company granted were the chief factor in enabling the Ministry to maintain the price of the metal on the London Metal Exchange at a satisfactory figure, which reacted on prices of lead in the United States, and saved the British Government many millions sterling. In addition, a satisfactory contract was entered into by which the lead production of the Fremantle Trading Company was secured. Both companies took steps to increase their production, and, as new plant was completed, the output increased until, at the beginning of 1918, the contracts placed by the Ministry secured a monthly output of 13,000 tons, equal to two-thirds of its annual requirements. Shortage of tonnage, however, prevented the shipment of the full amount contracted for.

Production in Burma, which was at the rate of 4,000 tons in 1913, more than doubled during 1914, and, after falling in 1915, rose to 17,000 tons in 1917. The annual production of Great Britain before the war was about 30,000 tons, but output declined during the war, falling to 12,500 tons in 1916. This was almost entirely due to a shortage of labour through recruiting.

II. First Efforts to Increase Supplies.

Shortly after the Ministry was established, a Lead Section of the Raw Materials Branch was set up, whose function it was to provide and maintain supplies of lead for munition purposes for Great Britain,

[1] See below, p 91.

together with the requirements of the metal for the Russian Government, and in part for the Italian Government ; to regulate the use and sale of lead in all industrial trades, and to prohibit the export of lead in any form except under licence from the Ministry of Munitions.

At the outset no immediate shortage appeared probable, but there was a great deal of speculation going on to the detriment of the Government. The following figures summarise the position for 1914 :—[1]

———	Imports into U.K.	Exports.	Home Consumption.	
	Tons.	Tons.		Tons.
From Spain ..	92,145		For Sheet Lead,	
,, Australia ..	68,519		Lead Pipes, &c.	100,000
,, U.S.A. ..	31,048		For White Lead ..	40,000
,, Mexico ..	1,735		For Lead Oxides ..	20,000
,, Greece and other countries ..	30,747		Lead shot, bullets, cable covering, &c.	10,000
Totals ..	224,194	53,984		170,000

By the prohibition on export of lead and a curtailment of the metal for home consumption it was estimated that the total imports would leave about 74,000 tons for munition requirements and for supplies to Russia, that is, of course, providing that supplies from the United States remained normal. Supplies from this source, however, had decreased 50 per cent. during September and October, 1915, from 2,773 tons in 1914, to 1,400 tons. British requirements for munition purposes during 1916 were estimated at 97,000 tons, 67,000 tons being for shrapnel bullets and 30,000 tons for rifle bullets. The Department had already purchased 14,000 tons on Russian account for delivery during the first three months of 1916, and, in addition, the Russian Government had requested the Ministry to purchase a further 41,000 tons to cover their requirements to the end of the year. Including Russian requirements, therefore, there was a demand for 152,000 tons for munitions purposes. These figures revealed a shortage of 82,000 tons, and if the export trade of the United Kingdom was to be maintained, the shortage would be increased by approximately another 50,000 tons.

In July, 1915, the Broken Hill Proprietary Company, of Australia, had offered to place the whole of their output—about 12,000 tons a month—at the disposal of the British Government, at a price of £21 10s. f.o.b. Sydney, the price of lead on the London Metal Exchange being then £20 5s. per ton ; but the Contracts Department thought it would be unwise to enter into a contract with one company for over two-thirds of the annual consumption of the metal. Eight thousand tons, however, were secured from the Broken Hill Company at an average price of £22 per ton, and in December, in view of the constantly increasing demand, the output of the company from 1916 onwards was

[1] Sir L. Llewelyn's Papers, 51.

secured. Contracts with the Penarroya Company, of Spain, and with the Fremantle Trading Company were also placed.[1] The quantity estimated to be delivered by the Broken Hill Company to the end of the year 1916, was 67,000 tons. By the contracts placed at the end of 1915 and early in 1916, the Department had thus secured about 102,000 tons, irrespective of the 14,000 tons bought for the Russian Government, while home production was expected to yield 30,000 tons. Any balance of requirements, including Russian needs, would have to be secured from America, Mexico and other sources. Production in Mexico and Greece being problematical, the only certain source of extra supplies was the United States.

III. Attempts to Regulate Prices by Agreement.

Another factor that increased the seriousness of the position was the unsettled state of the market. Speculation was rife, and German influences served but to embarrass an increasingly difficult situation. At conferences between representatives of the Department and members of the London Metal Exchange in January, 1916, it was decided that an attempt should be made to eliminate speculation by voluntary methods before resorting to compulsion under Regulation 30A of the Defence of the Realm Act, which was advocated by Mr. Llewelyn.[2]

Mr. Cecil Budd addressed the members of the London Exchange and pointed out to them the gravity of the position and the resolve of the Government to take very stringent measures in regard to dealings in lead unless the gambling element were eradicated. As a result, the price of lead dropped £3 10s. per ton in three days. In order to keep prices at a reasonable level, the Ministry then adopted the policy of placing small parcels of metal on the market in order to steady it. The position at this period was accentuated by the loss of two cargoes in torpedoed steamers, and the holding up of about 5,000 tons in Spain owing to lack of tonnage. Meanwhile, the American market was rising, being £2 a ton above London Exchange prices in February. Inquiries for big parcels on Russian account (at prices as high as £46 a ton), undoubtedly contributed to the maintaining of a price greatly in excess of London prices, while many inquiries for large amounts of lead were inspired by German interests in order to upset the market. By the end of March, in sympathy with New York, the price on the London Metal Exchange rose to £36 10s. per ton, the highest price since the Napoleonic Wars, but by this time supplies were beginning to come forward on the contracts placed in Australia and Spain, and the Ministry was able to supply the home market with small quantities. By the end of June, the London quotation had dropped to £28 15s., and the position became much easier. From July, 1916, onwards, the lead controlled by the Department was sufficient for the requirements of the country as then estimated, while the definite policy of avoiding competition between the different Government Departments and the ruinous competition of the Allies, especially the inexpert buying of the Russian Government, gave good results.[3]

[1] See below, pp. 94, 95. [2] Sir L. Llewelyn's Papers, 51. [3] 94/M/134.

At a conference between Mr. (later Sir Edmund) Wyldbore Smith, the Russian representative and the Raw Materials Department, it was agreed that their requirements should be purchased through the Ministry of Munitions. The merchants were informed accordingly, and from that date there was a steady fall in the market price.

IV. The Control of Lead, Lead Compounds and Lead Scrap.

There was some difference of opinion with the Contracts Department as to the general policy adopted in controlling the market, but after a conference with Sir Hardman Lever and Sir Frederick Black (June, 1916), the policy of the Raw Materials Department was approved. In the autumn of 1916, the Department had to face a shortage of the metal due to heavy shipments to Archangel, and to the delay in the arrival of Australian lead, which though shipped in June, was still afloat in October. In addition, the firm of Messrs. H. R. Merton and Company was disturbing the market by selling lead at very high prices, in direct opposition to the policy of the Ministry.

Messrs. Merton had been able to secure control in the United Kingdom for the ensuing year—1917—of " Sopwith " lead, which was essential to consumers of chemical sheet lead, while their dealings on the London Metal Exchange would react on the contracts with the Penarroya and Broken Hill Companies, in which the price was dependent upon the monthly average price of the London Metal Exchange. It was accordingly decided that the time was ripe to place all lead produced and imported into the country under the complete control of the Ministry of Munitions, and an order issued under the Defence of the Realm Act was published in the London Gazette on 2 February, 1917. This Order allowed the Department to exercise effective control over the market both as regards supplies and prices of unmanufactured lead, and forbade all sales or purchase of lead except by licence, and the use of lead for any work except that which came under certain priority classifications. Further, returns of stocks were required from all holders of lead. On 6 April, this Order was superseded by a more comprehensive one, which included white lead, lead oxides, lead manufacture, lead alloys or lead compounds of any kind, and a schedule of maximum prices was instituted. By a further Order, dated 1 September, 1917, the Minister of Munitions took possession from that date of all pig lead, whether virgin or remelted ; old and scrap lead, and residues situated in the United Kingdom except :—(*a*) such lead as might have been in possession of, or due under, an existing lawful contract in writing for future delivery for use in the manufacturers' own works ; (*b*) such lead as might be specially excepted under the written authority of the Minister of Munitions.

V. Agreements with the Australian Lead Producing Companies.

In December, 1915, as stated above, a contract was arranged with the Broken Hill Company, under which the British Government secured the whole output of the company from the beginning of 1916, with the exception of a quantity sufficient to satisfy the sellers' current

contracts with other buyers, an average monthly quantity of 500 tons for domestic consumption in Australia, and an average quantity of 1,500 tons per month for the requirements of the company's Eastern trade in China and Japan.[1] The price was to be the London Metal Exchange official average for the month of arrival, less certain discounts, and less 5s. per ton in lieu of war risk and marine insurance. In the event of any lead shipped being lost at sea, it was to be paid for at bill of lading weight at the London average price for the month following shipment.

It was the intention of both parties to the agreement that the contract should remain in operation until the conclusion of the war. The Broken Hill Company agreed to place their organisations in Melbourne and London at the disposal of the Ministry for the purpose of arranging shipments and distribution respectively, and in this way they were able to maintain touch with their regular customers in the United Kingdom and elsewhere, and thus ensure their goodwill being disturbed and endangered as little as possible.

In March, 1917, the contract was renewed, subject to a variation in the terms of purchase, which were £28 15s. per ton for soft lead, and £35 12s. 6d. for antimonial lead, both c.i.f. On account of freight difficulties, the contract was amended in June to f.o.b. Sydney or Port Pirie, payment to be made 85 days from date of rectification. This contract continued to run until 31 March, 1919.[2]

At the end of 1915, a contract was entered into with the Fremantle Trading Company which had just completed the erection of a smelting plant. The contract was for 5,000 tons, delivery during 1916, on the same terms as the Broken Hill contract.[3] In 1917, it was renewed for the whole production of the company's mines, and on similar terms to the Broken Hill Company. This contract was terminated on 31 December, 1918.

As in the case of other metals the Australian Government took steps to oust German interests from the lead industry.[4] All mineral and metal contracts with enemy companies and firms for the Commonwealth Government were cancelled, and the lead combine controlled by the Germans was dissolved. One of the results was the formation and extension of the Broken Hill Associated Smelters Proprietary Company Ltd., which took over the Broken Hill Proprietary works at Port Pirie. The new company had the largest silver lead smelting works in the world, having a capacity for an output of 200,000 tons of pig lead, and 5/6,000,000 oz. of silver per annum. The plant was also capable of handling large quantities of gold ores, concentrates, and other auriferous materials.

VI. Agreements with the Penarroya Company.

Negotiations with the Penarroya Company, which began in December, 1915, showed that any sale was dependent upon the British Government allowing the shipment of coke from this country to Spain for the company's use. A maximum price of £28 per ton was to be

[1] P.M./L/1828. [2] 94/L/1073. [3] 94/L/1114. [4] C.R.V./A/023.

fixed, the Government being allowed a rebate of £1 per ton as a concession for a guaranteed supply of coke. In view of the fact that the Spanish Government might place an export tax on lead, as had been the case with zinc, it was further arranged that the Ministry of Munitions should pay any such tax so long as the price quoted on the London market was below £28 per ton.[1] The contract subsequently entered into was for 18,000 tons of antimonial lead, the payment to be based on London terms.

In January, 1917, a fresh contract was entered into with the Penarroya Company, by which the Ministry secured 18,000 tons of soft lead, and 18,000 of antimonial lead over 1917.[2] This contract differed in several details from the previous one. The price was to be the average monthly official quotation in London, subject to deductions of £1 10s. per ton for Cartagena and Malaga lead, and £2 per ton for Tunis and Marseilles lead, and to an additional fixed rebate of £3 10s. per ton upon each shipment in consideration of the British Government carrying at their own expense, all risks included, from the East Coast of England to Cartagena, Malaga, Marseilles and Tunis as desired by the Penarroya Company, three quarters of a ton of coke or one and a half tons of coal, at the option of the Penarroya Company, for every ton of lead delivered by the company, the company's agents to be allowed every facility for buying and exporting the fuel. If during the period of the contract the Spanish, French or Tunisian Governments were to establish a tax on exportation of lead, this tax was to be borne equally by the two parties to the agreement.

VII. Centralised Purchasing: the Inter-Allied Lead Committee.

At an Inter-Allied conference in Paris, on 3 August, 1917, it was agreed to purchase the output of the four large companies controlling the Spanish output, at a price of 750 pesetas (approximately £30) per ton f.a.s. Spanish port, this price to be applicable to deliveries from 1 August, 1917, to 31 December, 1917.[3]

It was estimated that the Spanish production would be at the rate of 180,000 tons per year, and its allocation to the Allies was agreed to on the following basis :—

England	45/180
Italy	63/180
Russia	20/180
France	52/180

This allocation was to hold good until 31 December, 1917. It was further agreed that on account of the shortage of the metal each country must restrict its demands, and reduce them to war requirements and other essential needs of the country, and investigate the possibility of increasing its own resources by the development of its own production. The conference also expressed the wish that the Allied Governments should study the possibility of reducing the use of shrapnel, or of substituting some other metal than lead for shrapnel bullets.

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[1] (Printed) *Weekly Report*, No. 22, I. (25/12/15) ; Sir L. Llewelyn's Papers, 51.
[2] 94/L/923. [3] P.M./L/2194.

Further, the conference decided that it was desirable to create an Inter-Allied Lead Committee sitting at Paris, which would ensure purchases of lead or ore in Spain being effected by a single purchaser in each country, who would buy for the direct needs of the State, as well as for other needs, and communicate all his purchases to the Inter-Allied Commission. Pending the appointment of such a committee, it was agreed that none of the Allies should buy lead or lead ore in Spain except from one of the four companies who agreed to accept the price of 750 pesetas.

The defection of Russia from the Allied cause left the committee with an allocation of 20/180ths., which was allotted to Great Britain, making the British allocation of the Spanish output 65/180ths., and the purchase of this quantity was sanctioned by the Treasury on 6 June, 1917.[1]

The first executive meeting of the Inter-Allied Lead Committee was held on 8 December, 1917. Its duties were to divide between the Allied nations the quantity of Spanish lead that the Consortium contracted to sell to them. The willingness of the producers to accept the lower price was due to the fact that the miners' wages were based on the official London price, and thus the difference between the Allied price of 750 pesetas and the home (Spanish) price of 890 pesetas, and between the Allied price and the price charged to neutrals was clear gain, whereas if the Allied price had been raised to 890 pesetas, the miners would have drawn an increased wage on the whole production, and the profits to the companies would not have been so great.

The arrangements made by the Inter-Allied Committee did not materially affect the Ministry of Munitions contract entered into in the early part of 1917 with the Penarroya Company, except in so far as, with the addition of the Russian allocation, it increased the quantity by about 20,000 tons, and that it allowed a price of 750 pesetas instead of £30 per ton. In spite of the fall of the exchange to 20 pesetas to the £1, the price of 750 pesetas up to 31 December, 1917, was agreed to by all the Allies, who thought it was a large question of policy, and that it was necessary to make these alterations to obtain control of the European market and ensure a supply of lead.[2] The result of this policy was to create a European maximum price for lead, a point of the greatest importance, as the price in France during 1917 had been excessive and as high as £70 per ton. The Inter-Allied Committee was empowered to authorise the Consortium to deliver Spanish lead to neutral countries and to examine the price of such sale; to communicate to the four Allied Governments all decrees, laws, rules, etc., drawn up by each one of them on the subject of lead from Spanish sources and to fix the purchase price of Spanish lead.

The Committee met at regular intervals throughout 1918. It was empowered to revise the price after 1 January, 1918, but the price remained at 750 pesetas throughout the remainder of the war, in spite of the fact that the average price for Spanish lead as fixed by the Spanish Government was 890 pesetas.[3]

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[1] P.M./L/1828; P.M./L/2194. [2] P.M./L/1828.
[3] Minutes of Lead Committee, 12 July, 11 November, 1918.

VIII. Shortage of Lead and Control of Printers' Metal.

Towards the end of 1917 the position with regard to supplies became acute owing to the submarine menace and the shortage of freight. It was known that there was a great accumulation of old printers' metal in the country, and it was decided to secure this (as scrap) if possible. In response to an appeal by the Minister (12 December, 1917) a representative gathering of the printing and publishing trade met the Controller on 12 January, 1918, and it was agreed to ask the whole of the trade to assist the Ministry by releasing dormant metal, the amount being estimated at 25,000 tons.[1]

As printers' type metals were being sold at high prices for non-essential work, it was necessary to have an order under the Defence of the Realm Act making it illegal to deal in any used printers' metals at prices in excess of those agreed to by the printers and shrapnel bullet manufacturers who would use the metal. Under an Order dated 19 February, the following prices were fixed for used type metal :—

	Per Ton.
	£
(*a*) Type in case, including standing matter in chase and paper, on boards, and matter awaiting distribution	43
(*b*) Spacing material, including quads, quotations, metal furniture and leads	29
(*c*) Electro-plates and blocks	30
(*d*) Stereo-plates, metals and blocks	36
(*e*) Linotype metal	32
(*f*) Monotype metal	36

These prices included cost of packages and delivery f.o.r.

In June of the same year, owing to the easing of the position consequent on the cessation of supplies to Russia, it was decided not to make the Order compulsory, but it was arranged that the collection of metal voluntarily released should be continued. The total amount of metal so collected was 2,219 tons, of the approximate value of £77,000, and the expenses were £1,083, or 1·4 per cent.[2]

As a further precautionary economy the Priority Advisory Committee recommended that the export of sporting cartridges should be stopped, and a decision was also reached with regard to home consumption, the issue of metal for the manufacture being restricted and only issued under permit.[3] In reply to a circular, approved by the Government, sent out by the Ironmongers' Federated Association for the purpose of obtaining a return of cartridges and shot sold by ironmongers in this country, it appeared that, during the six months ending 25 September, 1916, 18,059,516 cartridges were actually sold to farmers and others for killing rabbits, rooks, pigeons and vermin that were interfering with the growing crops. During the same period, 103 tons 14 cwt. of shot were bought by ironmongers for loading cartridges.

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[1] Sir L. Llewelyn's Papers, 93. [2] *Ibid* [3] C.R.V./Gen./079.

Though the average monthly consumption of lead over the last six months of 1917 rose to 17,474 tons, or 210,000 tons a year, the situation was much easier, a working reserve stock of approximately 30,000 tons having been accumulated in this country, while stocks always afloat and in transit afforded ample security of supplies; for instance, in February, 1918, the amount afloat of Broken Hill lead alone was 25,736 tons. The Department felt justified, therefore, in releasing 1,000 tons of metal for the printing of the new Parliamentary Lists.[1] The situation was also much improved by Treasury sanction in May for the purchase of 40,000 tons in America at 7 cents per lb.

The average monthly consumption of metal for the last ten months of war, viz., January to October, 1918, was 18,000 tons, and at the beginning of November the amount of lead awaiting shipment in Australia was 62,882 tons.

The constructive policy adopted early in the war with regard to lead resulted in much lower prices for commercial requirements in the United Kingdom than in other countries. The contracts for Australian and Spanish lead permitted its sale to consumers at £30 per ton and all competitive buying was avoided.[2] By a system of careful rationing the supply thus secured was found adequate for actual necessities; the policy of controlling prices of commercial lead had been vindicated and was imitated abroad. In France the Government was content to cover its own requirements cheaply, and leave the balance to be scrambled for among ordinary consumers, so that prices reached as high as £70 per ton, but after repeated discussions, it was decided to adopt the principles successfully employed in England, and henceforth the price would be on a parity with the English figure.

IX. The End of Control.

When the war ended the Ministry was holding very large stocks of lead and had undertaken to accept Australian production up to 31 March, 1920. A conflict of interest between the Disposal Board and the Australian producers of lead was apparent as soon as the end of the Ministry contract with the producers was in sight. The Ministry wished to keep up prices in order to dispose of its remaining stocks without loss, while the Australian producers thought that a lower price would stimulate consumption of lead. The world's stocks in May, 1919, were about 350,000 tons, which was approximately the amount Europe had imported annually before the war. The Australian producers, therefore, had to face an unsold stock equal to a full year's requirements of the only importing countries in the world. The voluntary reductions of production in Spain, the United States and Australia, were not likely to be effectual, and it appeared that the only effectual remedy would be price reduction.

The Ministry, however, was anxious to liquidate its remaining stock of 160,000 tons, and was convinced that cutting of prices would not ensure any extra consumption of lead. It was decided, therefore, that

[1] (Printed) *Weekly Report*, No. 138, IV.A (20/4/18).
[2] *Mining Journal*, 17 November, 1917.

the Government and the Broken Hill Company should divide the available trade on the following terms: On a production of 120,000 tons per annum the Broken Hill Company were to be allowed to sell up to 75 per cent. and the Ministry 25 per cent., but on a production of 120,000 tons per annum the position was reversed, the Ministry was to sell up to 75 per cent. and the Broken Hill Company 25 per cent. of the extra production. His Majesty's Government and the Broken Hill Company were each to keep their own accounts and make their own sales, but it was agreed that a regular communication should take place with regard to sales effected, as it might be necessary to quote a fresh price to meet market conditions. This working arrangement was to be carried out by a committee of two, Mr. D. S. Robinson for the Australian Producers and Colonel Foster acting on behalf of the Ministry of Munitions. This arrangement was approved by the Rt. Hon. W. M. Hughes and afterwards confirmed by the Commonwealth Government. All control Orders which had been instituted were suspended from 17 December, 1918.

CHAPTER VII.

TIN.

I. Introduction.

The chief tin producing countries are the Federated Malay States, Bolivia, China, the Dutch East Indies, Nigeria, the Transvaal, and Southern Rhodesia. In 1917, nearly two-thirds of the world's supply came from the Malay Peninsula, chiefly from the State of Selangor, the bulk of the ore, after refining in the smelting works at Singapore, being shipped as pure 99·9 per cent. tin. The United Kingdom is also a producing country, and as tin is also mined in Australia, Tasmania and India, the Empire is in a much stronger position with regard to tin than any other metal. Outside British possessions the only tin producing countries are Bolivia, which supplies about 30 per cent. of the world's production, the Dutch East Indies, and China, the output of which is, however, mainly shipped and marketed from the British island of Hong Kong.

In 1893, the world's production was 68,300 tons; in 1912 production had risen to 125,718 tons, an increase of nearly 90 per cent. This latter production was as follows:

Tin in British and Foreign Ores raised in 1912.

British.	Metric Tons.	Foreign.	Metric Tons.
Malay States	47,995	Bolivia	23,168
Australia	6,745	Dutch East Indies ..	20,232
British Isles (Cornwall) ..	5,338	China..	8,783
Nigeria (North and South) ..	3,798	Siam	6,669
Union of South Africa ..	1,773	Spain and Portugal..	232
India, Burmah	287	Japan	198
Swaziland	200	United States ..	123
		Indo-China	101
		Austria and Italy ..	76
Total ..	66,136	Total ..	59,582

World's Total .. .. 125,718 tons.

Thus the British Empire raised 53 per cent. of the world's supply of tin, and no other nation furnished more than 20 per cent. Further tin smelted within the Empire totalled 85,956 tons or about 69 per cent. of the world's production. The consumption of Great Britain in 1912 was 27,350 tons, and of the Colonies about 5,150 tons, a total consumption for the Empire of 32,500 tons. As our mine production was 33,636 tons, and our smelter production 53,096 tons, in excess of our annual requirements, the British position was very strong. In comparison, it may be quoted that in 1912, the United States, which had no smelter production and only an output of 123 tons of ore, imported 49,296 tons.

There was therefore little need for anxiety about supplies of tin when the war broke out, but as a precaution, exports were restricted. A Tin and Rubber Committee, presided over by Lord Balfour of Burleigh was set up, and a licence had to be obtained from this committee before export was allowed.

Besides the manufacture of tin plates, the chief uses of tin for munition purposes were in the manufacture of solder, gun-metal, bearing metal and the lining of shells. Consumption in the United Kingdom at the end of 1915 had risen but little over pre-war figures; it was estimated at 30,000 tons per annum, 10,000 tons of which was used in the manufacture of tin plates. Prices remained steady, the highest for 1915 being £190 5s. as against £188 5s. for 1914 and £232 for 1913, while the lowest was £148 7s. 6d. as against £166 10s. for 1913.

II. Maintenance of Stocks.

The first note of warning was struck by Sir Cecil Budd, Chairman of the London Metal Exchange, who, on 10 November, 1915, called the attention of the Director of Materials to the desirability of increasing stocks in this country, which on 31 October, 1915, stood at 3,200 tons. He thought a bigger reserve should be created since opportunities for shipments from the Straits were becoming fewer each month, and with enemy submarines in the Mediterranean the risk of losses was greater. Further, supplies of tin smelted in England might be curtailed through shortage of labour due to enlistments, and the competition of newly started smelting works in the United States which had already taken away two important Bolivian ore contracts from English smelters. He suggested that exports to neutral countries should be curtailed in order to allow a reserve stock of at least 4,000 tons to be created. Moreover, it was desirable to refuse licenses for export to Denmark and Scandinavia whence the tin might go to Germany, where the price was £500 per ton, but such restriction of export would not be wise policy in the case of the United States, as it would probably have the effect of encouraging America to force her way still further into the Bolivian ore trade, and consequently decrease shipments of that ore to this country. The position at this time was that whereas the Tin and Rubber Committee controlled all exports from the Straits, there was no control over the metal in the United Kingdom. Indirect methods were tried at first, and the Metal Exchange was unofficially informed that it was the intention of the Government to maintain warehouse stocks in the country at a minimum of 4,000 tons.

In December, 1915, the Ministry requested the War Trade Department to withhold licenses for export, and in January, 1916, the export of tin was placed under the control of the War Trade Restrictions of Exports Committee acting with the advice and help of the Tin and Rubber Committee and the Raw Materials Department of the Ministry of Munitions. Tin plates and all receptacles made from tin plates were placed on the " A " list of prohibited exports, while tin and alloys of tin were placed on the " B " list.

Throughout 1916, markets remained quiet and normal under the influence of the export restrictions. Opening on 3 January, at £171 per ton, the price rose to £179 by the end of that month, and on 10 April reached £205, the highest settlement price of the year. Stocks in London and Liverpool that week totalled 2,834 tons and arrivals in course of landing 800 tons. From May onwards the market declined just as steadily as it had risen and by the end of July had fallen to £166. There were the usual fluctuations until the close of the year, when the market stood at £178 10s. per ton, and stocks in London and Liverpool were 3,322 tons and arrivals in course of landing 1,325 tons.

III. Heavy Demands from France.

The next step towards control was taken as a result of heavy demands from France and Italy. The normal pre-war consumption of tin in France was estimated at about 7,000 tons per annum, nearly all of which came from the British Empire. Her demand rose rapidly during the war. Licenses for 10,877 tons were granted by the Tin and Rubber Exports Committee during 1916, and for the first four months of 1917 the committee licensed the shipment of 6,255 tons, which is at the rate of 18,765 tons per annum. These increasing demands caused some anxiety.

At a conference on the question between Lord Balfour, the Director of Materials, Sir Cecil Budd, and Mr. Rucker (May or June, 1917), Lord Balfour pointed out that the French had been getting a considerable quantity of tin through private sources, and that great pressure had been brought to bear through the French Embassy for further quantities to be sent from this country. It appeared to be doubtful whether the French had been giving precedence to military requirements over commercial demands, while Italy with a pre-war consumption of 2,500 tons received licenses in 1916 for 3,289 tons. America had not been allowed to exceed her normal importation and it would be impossible to cut down her demands further without endangering the large supplies of canned foods for the Allies. In spite of the fact that the consumption of tin in England was well below the pre-war level the position was becoming serious. Owing to enemy submarine action, great difficulty was being experienced in maintaining the importation of tin ore from the West coast of South America, which had been at the rate of 25,000 tons in 1916. Stocks were down to 2,463 tons, while the price had risen £35 per ton in a month. It was therefore proposed that all orders for France and Italy should be given by the Commission Internationale de Ravitaillement, no other sales being allowed. Existing contracts, of which full particulars would be required, would be executed, if and when the necessary licences were granted.

A Press notice was issued appealing for economy in the use of tin, which was not yet legally controlled, asking for returns of all third party holdings, and pointing out that sales to France and Italy should be made through the Commission Internationale de Ravitaillement. The effect of this instruction was that the Materials Department

gained the knowledge of all third party holdings of tin in this country ; it also insured that all tin sold to France and Italy was for war purposes, and ascertained approximately the quantities required by these countries for war purposes.

IV. Agreements with France and Italy.

At an inter-Allied conference held in London on 5, 6 and 7 June, 1917, it was agreed that the British Government would grant export licenses for the French Government to receive, subject to freight being available, 1,100 tons of tin per month as from 1 January, 1917, the French Government in return giving favourable consideration to the question of controlling the use of the metal in France and restricting its employment to essential war purposes. In regard to tin plates an average delivery of 5,000 tons per month was accepted.

Subject to freight being available, Italy was allocated 1,000 tons for the second half of 1917 and Russia 6,075 tons. An offer of 1,000 tons per month of tinplates did not satisfy the Italian representatives, but they agreed to examine the demands afresh with a view to their reduction by restricting the use of the plates to strictly war purposes.

The agreement with France was confirmed at an Allied metal conference held on 22 June, 1917. All French requests for tin, whether for national defence or ordered by private firms, were to pass through the Commission Internationale de Ravitaillement, which would only sanction orders for tin required for government work. The Commission then passed the order on to the Tin and Rubber Committee for their approval or refusal.

The effect of the agreement arrived at with France and Italy was to limit market operations, and for four months—June to October, 1917—the market remained very steady at between £244–£250 per ton. Stocks in this country had also been increased to over 3,500 tons. Later, heavy purchases of Chinese tin by America at high prices reacted on the British market, which rose to £277 in November and £308 10s. by 19 December.

V. Control of Tin by Order.

Tin was therefore placed, on 19 December, under Regulation 30B of the Defence of the Realm Act, in the hope of restraining the advancing market. The market immediately fell £6 per ton, and a further and larger fall to £263 followed on 28 December, on the announcement of the Tin and Rubber Committee that no licence would be issued for export from the United Kingdom to the United States, as all shipments for America would be shipped direct from the Straits. An even more satisfactory feature was that an equally sharp fall took place in the Straits, where the Chinese had been holding the market persistently above London parities. By the end of the month the market was fairly steady at about £295 per ton.

At the same time, in order to establish a closer control of speculative transactions, suggestions for restrictive regulations for dealings in tin, drawn up and submitted by the London Metal Exchange, were accepted by the Minister.

Unfortunately, the good effects hoped for from the placing of the metal under regulation and from the restrictions imposed by the London Metal Exchange were neutralised during the last week of February by the loss of 1,400 tons of tin in the s.s.'s "Glenartney" and "Eumæus," and by small shipments from the Straits. Available supplies were reduced to 1,500 tons, and consequently the market was seriously short of the metal for prompt delivery. Spot tin advanced to £319, and if it had not been for the control exercised on the Metal Exchange which instituted a system of licensing to ensure that the available tin was only used for purposes of national importance, the price would have risen even higher.[1] In the Straits the price rose to £325 and later to £377, while at the same time America was paying over £500 per ton for Chinese tin.[2] On 26 April, 1918, therefore, an Order was issued forbidding all sales or purchases of tin without licence, restricting the use of tin to Class A work under the Priority Order of 8 March, 1917, and calling for returns of stocks, sales and contracts, but owing to the world shortage and the need of stimulating output, it was not considered expedient to fix a maximum price.[3]

The use of substitutes for tin as food containers, etc., and the development of detinning processes were also pressed forward.

VI. Proposal to Transport Straits Tin via America.

Heavy losses through submarine action during the early months of 1918, and the risk attendant on future consignments led to a suggestion being put forward by the American War Industries Board that all tin coming to the United Kingdom from the East should be shipped to the West Coast of America, railed across the Continent and re-shipped from an Atlantic port. Whether the smaller risk of loss by submarine would outweigh the disadvantages of bringing all the tin required for Europe across the Pacific was a moot point.

From a supply point of view the Materials Department viewed the proposal with misgiving. The cost of transport to the United Kingdom of Straits tin would be £37 2s. in lieu of £31 10s., while the journey would occupy at least ten weeks, and probably longer, as compared with eight weeks from the Straits. This would mean a permanent loss of 2,000 tons held up in transit until direct shipments could be resumed,

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[1] C.R.V./Gen./2157; (Printed) *Weekly Report*, No. 133, IVA (9/3/18).

[2] It is interesting to note that although during 1918 the price of tin rose to an abnormal figure the increase over pre-war levels was not nearly so great as in the case of other metals :—

	Rise in prices.
Copper	100 per cent.
Spelter	150 per cent.
Lead	70 per cent.
Aluminium	170 per cent.
Tin	67 per cent.

[3] C.R.V./Gen./2187

and as stocks in this country were less than one month's consumption of Straits tin, any traffic congestion on the American railways or at ports might result in England, France and Italy having no refined tin. Moreover, the proposal would have the effect of making America the stockholder of the entire output of British and foreign tin in the East. The Department therefore asked that before the War Industries Board's suggestion was accepted the matter should be fully discussed by the Inter-Allied Tin Executive, which was then being formed, and this was agreed to.

VII. The Formation of the Inter-Allied Tin Executive.

Proposals for setting up an inter-Allied organisation to control supplies of tin were discussed at the Paris conference, on 20 and 21 February, 1918, when it was decided that a further conference should be held to study the requirements of each country and the measures taken to guarantee that the use of tin was actually reserved for war purposes, to consider the possibility of dividing the world's output of tin between the Allies, including the United States, and of centralising all the purchases of tin for the Allies in the hands of an inter-Allied organisation.

On 22 April, Lord Reading cabled from Washington that the War Trade Industries Board urged that an international committee should be set up to control and distribute available supplies of tin.

The procedure proposed was as follows :—

(1) An Inter-Allied Central Bureau in London was to be constituted by the Governments of Great Britain, France, Italy, Japan and the United States and composed of one or more representatives of each of these Governments.

(2) An agreed allocation was to be made to each country of the supply available for its essential requirements, subject to such revision and readjustments as might be demanded from time to time by changing conditions in accordance with the best interests of all concerned.

(3) An agreed allocation was to be made among the countries concerned of the world markets, in which each might purchase tin and their respective shares of the purchasable supply of tin in such markets.

(4) Purchasing agencies were to be established in each market for purchasing under the direction of the Central Bureau the supply allocated to each country participating.

(5) From time to time, under the direction of the Central Bureau, the maximum and/or minimum prices to be paid in the different markets were to be regulated with the view, on the one hand, of preventing price raising by competition buying and, on the other hand, of stimulating production by increasing the profits of producers.

The American War Trade Industries Board, at a conference held on 18 April with representatives of the Embassy and of the War Mission, had stated that the system under which Straits Settlements

tin was sold and shipped to the United States under licence from the Rubber and Tin Exports Committee was unsatisfactory, firstly, because the supplies coming forward were not being maintained at the necessary level, and secondly, because, even after allowing for all differences in overhead charges, American importers and consumers (with the exception of the United States Steel Corporation, who had their own purchasing agent at Singapore) were obliged to pay a much heavier price than British consumers for the same tin.

Under the scheme put forward by the War Trade Industries Board the purchasing agencies in the Straits and Dutch East Indies would obtain their supplies through the usual channels, as the scheme did not involve the elimination of merchant houses, but aimed at the reduction of prices by the cessation of competitive buying. Lord Reading criticised the scheme as follows :—

> "We do not think adoption of scheme in its present form will tend to increase output of ore, and we realise that it contains objectionable features, but we understand that suggestions of a similar character were made recently at Paris Metal Conference, and we consider it essential that some means should be devised to remedy any inequalities of price above referred to."

The United States Government stated that they would require "for essential war products for United States and Allied Governments" approximately 80,000 tons of tin per annum, of which 36,000 tons must be obtained from the Straits. The British Mission had pointed out that little or nothing had yet been done to prevent the use of tin for non-essential purposes, but were met with the suggestion that nothing really effective could be done in that direction until the United States Government became the sole purchaser and distributor of the country's supplies.

On 30 April, Lord Reading cabled that the United States Government favoured the creation of a separate Inter-Allied Bureau in London to deal with tin and tungsten. A departmental conference was summoned on 17 May to discuss these proposals, at which the Non-Ferrous Metals Allocation Committee, the Rubber and Tin Exports Committee, the Foreign Office, the Colonial Office, the Board of Trade, the War Priorities Committee, the Commission Internationale de Ravitaillement and the Priority Department were represented. The Chairman, Mr. Rucker, pointed out that the principle of central purchasing for the Allies had been discussed and adopted at the Paris conference held in the previous January, so that the proposal of the United States was not new. They were now faced with an unnatural and abnormal position, as for some time past Dutch and Chinese prices had been £70 per ton higher than Straits prices. The only solution would seem to be to establish a universal level world's price through the medium of a Central Purchasing Committee.

It was recognised that one of the chief difficulties was the heavy demand for tin from the United States. Figures were quoted which showed that the production of tin plates in America had practically

doubled since 1913, and was still increasing, while the production of plates in South Wales had decreased to one-third of its peace level, so that British requirements for tin had actually dropped during the war.

	United States Output. Tons.	*British Output.* Tons.
1911	713,000 ..	816,000
1912	877,000 ..	847,000
1913	762,000 ..	822,000
1914	866,000 ..	800,000
1915	983,000 ..	762,000
1916	1,139,000 ..	632,000
1917	1,400,000 ..	390,000

The conference approved in principle the establishment of such a Central Bureau provided that the negotiations for its establishment were conducted in London, and the Bureau took the form of an Advisory Committee located in London to advise on the policy to be adopted in regard to the purchase of tin and the allocation of such purchases. Further, the executive power for carrying out such policy should be vested in the Non-Ferrous Materials Department of the Ministry of Munitions in London. Such an organisation would, it was hoped, result in a reasonable world's price for tin and in the restriction of the use of the metal in all the Allied countries to war and essential purposes only.

Mr. Baruch, of the War Industries Board, urged that the negotiations should be carried on in America. The most important point from the American point of view was to secure a definite allocation to the United States of 60 per cent. of the production of Straits tin and 66 per cent. of the world's production. The War Industries Board also wished for the establishment of a purchasing and distributing agency in each country. It took the view that the proposed Inter-Allied Bureau should play no part in determining the allocation of the world's output of tin among the Allies. The work of such a bureau should be confined to administering the distribution of tin on a basis already determined and to controlling the prices to be paid by the national purchasing agencies. In a later cable Lord Reading reported that Mr. Baruch was pressing for an unconditional allotment of 3,000 tons per month.

These cables were considered at a conference held on 3 June, when the Materials Department, the Rubber and Tin Committee, the Foreign Office and the Colonial Office were represented. It was pointed out by the representative that the Colonial Office would offer serious objections to Malay Straits tin being controlled by any Inter-Allied Board, but that there would probably be no objection to the output being taken over by a British Government Department which could allocate the tin in conjunction with an Inter-Allied Board.

Lord Reading was therefore informed that the Ministry of Munitions agreed to an allocation to America of 60 per cent. of the Straits tin output, provided always that the output of British smelters was not reduced below 28,000 tons per annum. Should there be any reduction in the output of British smelters due to lack of Bolivian ore,

such deficiency was to be made good from the 60 per cent. of the Straits tin allocated to the United States. The Ministry of Munitions was unable to estimate the tin output of the Straits Settlements and could only agree to a percentage of production instead of a definite quantity being allocated to America.

The American suggestion that all Straits tin should be shipped via America could not be accepted, as the extra time taken in transit from the Straits to England was about two months, and there were not sufficient stocks in the country to meet British requirements. The Ministry of Munitions could not agree to allocate two-thirds of the world's production of tin, but agreed to keep out of the markets of Banka, China and Billiton, so long as the maximum price was not exceeded and conditions of production remained unchanged.

The establishment of a sole purchasing and distributing agency to handle all purchase of tin and tin ore in each country was agreed to by the Ministry of Munitions provided that a uniform price was accepted. Further, with regard to the composition of the Inter-Allied Central Bureau, the Ministry agreed that one or more representatives from countries participating should be included, and that the Bureau should exercise such general supervision and control over the machinery set up in each country for the purchase of tin and tin ore as might be necessary to safeguard established trading interests, provided that the activities of such established interests did not interfere with the efficiency and economical working of the general plan.

The Ministry pointed out that the whole of the tin available in Britain was used exclusively for war purposes and, in addition, Britain was called upon to supply tin for her Allies who had guaranteed that such tin was used exclusively for war purposes. In addition, Britain had to export tin to Argentine and Uruguay for meat imports.

Subsequently, American representatives visited England, and, on 21 August, a conference was held at which all the Allies were represented. The proposal for the establishment and composition of an Inter-Allied Tin Executive under the chairmanship of Sir Leonard Llewelyn, was agreed to. The agreement, which is printed in an Appendix,[1] provided for the allocation of tin to the Allies, for the establishment of buying agencies, for the fixing of maximum prices, and for economies in the use of tin.

VIII. The End of Control.

On 17 December, 1918, the Rubber and Tin Exports Committee suggested that the time had arrived for the abandonment of all restrictions on the export of manufactured tin goods, except to enemy countries.[2] The Non-Ferrous and Raw Materials Committee agreed, 2 January, 1919, that there was no reason for the further control of the export of tin excepting in so far as might be necessary in the case of countries effected by the blockade.

This decision was accepted, and the Tin Executive and the Tin Section of the Ministry ceased to function at the end of January, 1919.

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[1] Appendix VII. [2] Sec./Gen./373.

CHAPTER VIII.

PLATINUM.

I. Introduction: Sources of Supply.

The importance of platinum in the carrying out of munition programmes was considerable. It was used in the production of sulphuric and nitric acid, which were essential to the manufacture of high explosives and propellants, in the manufacture of magnetos for motor engines, of scientific and surgical instruments; for X-ray tubes, fuses; for firing charges in guns of large calibre; for telephone, telegraph, and wireless installations. In addition, it was largely used by the dental profession. Requirements for war and essential purposes were therefore large, but there was only a limited supply.

The chief producing country is Russia, the only other appreciable contributor being Colombia. There are non-alluvial deposits of this metal in Australia and Canada, but the total output of the British Empire during 1916 was only 282 ozs., about 25 per cent. of the world's production. The total output of crude platinum for the three years preceding 1914 was :—

	1911	1912	1913	1914
	ozs.	*ozs.*	*ozs.*	*ozs.*
Russia	300,000	300,000	250,000	241,000
Canada	30	30	50	30
New South Wales & Tasmania	470	778	1,275	1,248
Colombia	12,000	12,000	15,000	17,500
United States	628	721	483	570
Borneo, Sumatra	—	200	200	—

It will be seen that even before the war Russian production was decreasing, and the only sources of increased supply were Colombia, Australia, and Tasmania. The output of Russian refined platinum reached its zenith in 1901, with a production of 204,863 ozs.[1] After that production steadily declined. In 1912, it was 177,478 ozs. of refined platinum; in 1913, 157,465 ozs.; in 1914, it had fallen to 156,939 ozs.; in 1915, to 108,488 ozs.; and in 1916, production was only 78,732 ozs.[2] This decline, apart from reasons connected with the war during the latter years, was due to the exhaustion of the best deposits, the lack of technical equipment and spare parts, the French

[1] Admiralty Memorandum for Restriction of Enemy Supplies Committee, 23 July, 1918. (D.F./Russia/3.)

[2] These are the official figures, but are likely to be an under-statement owing to illicit dealings.

quasi monopoly of the refined metal, and the calling up of miners for military service, combined later with general sabotage and industrial chaos. All these factors combined to affect output adversely. But against this, the production for 1917 up to July was reported to be 84,262 ozs., which showed a considerable increase on the output of 78,732 ozs. for the whole of 1916.

Next in order to Russia as a producer of platinum comes the Republic of Colombia, in Central America. The deposits lie on the head waters of the San Juan river, and before the war an American company produced about 25,000 ozs. of crude platinum annually from these deposits. This crude platinum was shipped to the United States and there refined. Exports of platinum from Colombia to the United States from 1910 to 1914 were:—

	Troy ozs.	*Value.* $
1910	1,600 ..	31,383
1911	5,503 ..	147,820
1912	6,627 ..	219,128
1913	10,461 ..	363,731
1914	12,387 ..	398,657

In view of the economic and military importance of stimulating the supply of platinum,[1] Treasury sanction was given in 1918 for an issue of capital by the British Platinum and Gold Corporation, formed for the exploitation of mining properties in Colombia, while the Ministry of Munitions granted a priority concession for the construction of the corporation's first dredge.[2]

The production of native platinum in the United States was on a small scale ; only 605 ozs. of crude platinum were sold in 1917, this being 100 ozs. less than sales during 1916. On the other hand, imports of crude platinum for refining were on a large scale, amounting to 31,921 ozs. in 1917, not counting the 21,000 ozs. of Russian crude platinum which was received by the Government in December. During 1917, refiners made about 33,000 ozs. of platinum, 4,800 ozs. of palladium, 833 ozs. of osmiridium, and 210 ozs. of iridium. The saving of scrap platinum of all classes resulted in much larger recoveries of secondary platinum metals than in previous years, a total of 72,000 ozs. being recovered as compared with 48,000 ozs. in 1916.

The recorded production of Canada for 1918 was 39 ozs. (crude), equivalent to 25 ozs. fine, valued at $2,560, as compared with 57 ozs. (crude), valued at $3,823 in 1917. This was all obtained from the Similkameen district of British Columbia. The most important sources of the metal are the nickel-copper areas of the Sudbury district of Ontario. On the basis of the reports from the Canadian Copper Company, the total matte shipments in 1918 would contain, among other precious metals, 8,677 ozs. of platinum and 13,016 ozs. of palladium.[3]

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[1] *Report of Dominions Royal Commission on Natural Resources.*
[2] *Financier*, 16/7/18.
[3] *Board of Trade Journal*, 12/5/19.

II. Responsibility for Supply Transferred to the Raw Materials Department.

Up to October, 1915, Lord Moulton's Committee on High Explosives had arranged for supplies of the metal for its own purposes and for outside contractors. Platinum had, by this time, become difficult to procure, and at the request of the Committee and with the sanction of the Director-General of Munitions Supply, the Raw Materials Department undertook responsibility for supply.[1] Platinum was not then on the list of prohibited exports, and the department promptly requested its inclusion. Further, they instructed Messrs. Johnson Matthey and Company, of London (who were acting as Government agents), to purchase 80 poods, equivalent to 30,000 ozs., in order to improve the position of the Government, which was then short of its requirements by 21,462 ozs.,[2] considerable responsibility having been undertaken for the supply of platinum to American contractors :—

Requirements.	*ozs.*
Messrs. Dupont—Contracts for H.E. in America ..	17,240
Messrs. Dupont—Requirements for new contracts to be placed	20,000
Messrs. Johnson Matthey—Supplies for Committee on High Explosives	19,868
Reserve stock to be created for Ministry	20,000
Sundry contracts at home and abroad	13,720
Total ..	90,828

Supplies.	*ozs.*
Messrs. Morgan Grenfell—Russian purchases for Messrs. Dupont	11,365
Messrs. Johnson Matthey—from France	16,000
In stock	17,101
In course of transit	12,700
Purchases in Russia	12,200
Total ..	69,366

Negotiations were in progress for the purchase of an additional 29,080 ozs. in Russia,[3] but provision would also have to be made for the requirements of other Government departments, Government contractors, and commercial purposes, which were estimated at 500 ozs. per week.

The situation was thus at this period regarded as satisfactory, but, as only 52 per cent. of the supplies required were in the United Kingdom, the position was liable to variation at any moment, and in order to eliminate competition, it was decided that the balance of platinum required by Messrs. Dupont should be supplied through the Ministry of Munitions, instead of being bought by Messrs. J. P. Morgan.[4]

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[1] (Printed) *Weekly Report*, No. 12, I. (16/10/15).
[2] *Ibid*, No. 14, I. (30/10/15).
[3] Minutes of Finance Committee on Economy, 29 May, 1916.
[4] (Printed) *Weekly Report*, No. 16, I. (13/11/15).

III. The Platinum Control Order.

It became necessary soon after responsibility for supplies was assumed by the Materials Department to issue an Order under Regulation 30A of the Defence of the Realm Regulations (31 December, 1915), and at the same time a circular letter was sent to known holders of platinum, instructing them to make a return of all platinum in their possession within three days. These returns showed that 8,681 ozs. of the metal were held by dealers, a much larger stock than had been anticipated.[1] Subsequently, a requisition notice was sent to holders of the material requisitioning all their platinum at 190s. per oz., the market price of platinum being then 210s. per oz.[2] The jewellery trade protested strongly, and finally it was agreed to pay the actual cost for such part of their requisitioned stock as they could prove, by invoices, to have been purchased at a higher price than 190s. per oz. The Ministry's maximum price, however, was limited to 220s. per oz., and owners were authorised to keep all stocks purchased by them at a price above this figure. As jewellers were not allowed to use their stocks for the manufacture of jewellery, they sold them, in many cases, to the Ministry at the maximum price of 220s. per oz.

After discussion with representatives of the dental profession, a ration of 200 ozs. per month based on a percentage of the firm's purchases during the previous year was allowed them.[3] Most firms at the time were making teeth containing a solid platinum pin, but as the ration was reduced from time to time, manufacturers were driven to use a substitute, this in most cases being a platinum alloy, or a platinum sheathed wire. As the price of platinum gradually rose, and the substitute became more generally used, it paid dental manufacturers to break up their stocks of solid platinum pin teeth and use the material thus salved for the manufacture of substitute pins. By June, 1916, however, the purchases made by the Ministry ensured ample supplies, and manufacturers were granted permits to purchase as much metal as they required.[4]

In order to make full use of dormant stocks, permits to continue dealings in platinum were issued to small jewellers and watchmakers who dealt in second-hand articles, and to the dealers whose business it was to call on householders and purchase any old gold, silver, or platinum which they might have for disposal. About 350 of these permits were issued, and very few of them had to be cancelled owing to infringement of the conditions under which they were granted. The amount of scrap platinum collected in this way was :—

	ozs.
1916	25,000
1917	15,000
1918 (6 months)	6,500

The receipts for the last half of 1918 tended to show that practically the whole of the dormant stocks of the material had been collected.

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[1] (Printed) *Weekly Report*, No. 25, I. (15/1/16).
[2] This compares with a price of 185s. in 1913 and 1914.
[3] (Printed) *Weekly Report*, No. 29, 1 (12/2/16).
[4] *Ibid*, No. 46, IV (17/6/16).

Under the control order, the Ministry of Munitions became the sole purchaser abroad for British requirements, and the sole holder of stocks in this country. Consequently, it was able to fix its own selling price, which was raised from time to time in accordance with the increased cost of the metal :—

1916—January	Purchasing price	190*s.*
	Selling price	200*s.*
August	Purchasing price	200*s.*
	Selling price	220*s.*
December	Purchasing price	260*s.*
	Selling price	290*s.*
1918—February	Purchasing price	360*s.*
	Selling price	400*s.*[1]

The metal was bought at favourable prices. Thus, in November, 1916, 17,500 ozs. were bought in Russia for Faversham Explosives Factory, at prices varying from £13 7s. 9d. to £11 10s. per oz., the price in America then being £21 16s. per oz. and in Paris £14 11s. per oz.

All the stocks of platinum in the country were held for the Ministry by Messrs. Johnson Matthey. All purchasers had to obtain a permit for their requirements from the Materials Department, and these permits were only issued for essential purposes, while dealers were only allowed to keep small stocks.

IV. Requisitioning of Russian Output.

As has been seen, the Russian output of platinum declined rapidly during the war, the output for 1917, 84 poods, being only a quarter of that for 1914. Early in 1917, the Russian Government (Mining Department) requisitioned all platinum produced in Russia, and, as a consequence, all contracts entered into by the Ministry with mine-owners were cancelled. The Mining Department, however, were prepared to supply 30 poods of platinum to the Ministry at the requisitioned price, but demanded cash payment before the metal was released. These conditions were accepted by the Finance Department, the money being transmitted to H.M. Ambassador, Petrograd, for payment.[2]

V. Joint Action with America.

There were signs in May, 1917, that America was short of platinum, a request being received by Messrs. Johnson Matthey from a New York firm (who it was thought were probably acting for the American Government) for a supply of 15,000 ozs. Owing to a big reduction in the Explosive Supply Departments requirements, Ministry stocks totalled 35,000 ozs., this being 15,000 ozs. in excess of the Government reserve of 20,000 ozs. which it had been decided to build up The view held by the Ministry advisers was that if the American Government, or their brokers, entered the Russian market, the action would, in all probability, raise the price of the metal to an exorbitant figure, whereas the Ministry, having ample supplies, could meet the American needs and thus keep them out of the Russian market. The

[1] The rise in price in 1918 was due to the increased requirements of America and France.

[2] D.F.1/Russia/3.

Ministry, therefore, through Mr. Layton, who was then in America, offered to supply the American Government with the 15,000 ozs. of platinum they required at cost price, conditionally upon their not entering the Russian market without first consulting the Ministry.

After discussion with the American Department of Commerce, Mr. Layton reported that the American Government were prepared to co-operate with the Ministry in the purchase of platinum, and though there was some difficulty with a committee of American platinum refiners, who, in June, stated that they intended to buy independently in Russia if they thought they could make a better bargain, the agreement that all purchases should be made by the British Government was adhered to (August, 1917).[1]

Joint action in this matter continued, and when, in February, 1918, American supplies became short, a loan of 10,000 ozs. from the British Ministry was asked for in the hope that this would enable the American Government to avoid buying 10,000 ozs. which were offered from Russian sources and bring about a reduction in Russian and Colombian prices. The Ministry, however, took the view that if any attempt was made to lower prices it would in all probability result in decreased output, and advised the American Government to close with the offer of 10,000 ozs. from Russia.[2]

In July, 1918, an offer was made to the British agent in Petrograd by the Russian authorities of 50 poods, and in agreement with America this offer was accepted. The price was £28 per oz. of crude platinum, this being equivalent to £34 16s. per oz. of refined metal. Treasury sanction to the purchase was at first refused, but on a further application the Treasury sanctioned the purchase on behalf of the British Ministry of 12½ poods, the balance of 37½ poods being left to the Americans.[3]

VI. The Inter-Allied Agreement.

The increasing shortage of platinum, and the proved value of joint action by the British and American Governments, led to a movement for joint action by the Allies generally in the control and distribution of platinum and platinum metals. A sub-committee of the Inter-Allied Non-Ferrous Metals Committee recommended (October, 1918) that the Governments of Great Britain, France, Italy, and the United States be requested, through the proper channels, to enter into an agreement to form an Inter-Allied Platinum Executive.[4]

Under the agreement[5] subsequently entered into by the representatives of the chief Allies, it was arranged that all purchases of platinum should be for the joint account of all the Allies who were parties to the agreement, their respective shares being allocated in direct proportion to their war requirements, as determined by the Inter-Allied Munitions Council.

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[1] (Printed) *Weekly Report*, No. 90, III. (5/5/17); No. 94, III. (2/6/17); No. 100, III. (14/7/17); No. 107, III. (1/9/17).

[2] (Printed) *Weekly Report*, No. 131, IVA (23/2/18).

[3] D.F.1/Russia/3.

[4] Minutes of Inter-Allied Non-Ferrous Materials Committee. (M.C. 832.)

[5] Appendix VIII.

Provision was made for the appointment of a Director of Purchases in London, and buying agencies in any or each of the producing centres, and also for the allocation, or disposal, of all platinum produced in any of the participating countries. Powers were also given under the agreement for fixing prices to prevent price-raising by competitive buying, or for the purpose of stimulating production by increasing the profits of producers. Further, the Executive was given power to pool all purchases, both as to quantity and price. This agreement was for the period of the war, and with the cessation of hostilities, within a month of its being entered into, it automatically became void, no transactions having been carried through under its provisions.

VII. Liquidation of Stocks.

Government stocks of platinum, which on 31 December, 1918, totalled 53,000 ozs., were increased by further receipts of the metal under existing contracts, making a total of 67,427 ozs. to be disposed of. The Ministry decided that a price of £22 per oz. should be maintained in spite of protests from the trade, which argued that, as numerous substitutes for platinum were in use owing to the scarcity of the metal during the war period, it was desirable to lower the price to win back the pre-war demand for platinum. The Raw Materials Committee anticipated that little platinum would be forthcoming from Russia, and that there was likely to be a shortage of platinum during 1920, and decided on a policy of restricting the amount of its stocks to be disposed of each month, the figure of 2,000 ozs. a month being generally approved.[1]

In April, 1919, the desirability of coming to an agreement with the French became apparent, as their price was £19 10s. per oz. against the British Ministry price of £22 per oz. for small quantities, and £20 per oz. for large parcels, at which price a sale of 2,000 ozs. had been made to the Americans.

British and French stocks at the end of March were, approximately, 70,000 ozs., while American stocks bordered on 40/50,000 ozs. These latter, it was stated by Mr. Summers, acting for the American Government, his Government proposed to retain as a Treasury reserve, which left the French and English Ministries free to arrange a mutual agreement for disposal of stocks. After prolonged negotiations, Messrs. Johnson Matthey agreed to undertake the sale of Government stocks at a remuneration of 1 per cent. It was understood that the firm were to give preference in every case to requirements for home trade over those of buyers for export. It was subsequently discovered that French Government stocks were only 100 kilos (3,215 Troy ozs.). This was only two months' sales in accordance with the agreement, so that from 1 July the British Ministry were free to take independent action.[2]

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[1] Minutes of Raw Materials Committee, 2/1/17. (HIST. REC./R./264.2/7.)
[2] *Ibid.* 5/6/19.

Prices were maintained by agreement with the United States (25 June, 1919), and the Ministry continued its policy of holding its stock of about 60,000 ozs. for slow liquidation, conserving it for essential and commercial purposes, and selling not more than 2,000 ozs. per month at £22 per oz. France had disposed of the stocks, except about 3,000 ozs., to private buyers at practically the same price.

In reply to a request from the United States for platinum the Ministry replied that it had no platinum for disposal in America, and that all stocks were needed to meet home requirements,[1] the Committee's view being that with a still limited world-supply, it was undesirable to encourage export sales of a material for which there was an unceasing demand for British industry,[2] while they placed little credence in the repeated rumours that large Russian stocks were about to be placed on the market.[3]

The policy of the Ministry was justified by the steady demand for platinum for the home trade at £22 per oz. The selling price was increased to £25 per oz. in December, 1919, and to £37 10s. on 17 January, 1920, when the Government held a stock of 32,000 ozs. The approximate profit on liquidation was £1,150,000.

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[1] Cables, C.G.154, A.B. 10934.
[2] Minutes of Raw Materials Committee, 30/10/19.
[3] *Ibid*, 22/7/19.

CHAPTER IX.

OTHER NON-FERROUS METALS.

I. Antimony.

(*a*) The Sources of Supply.

The principal source of antimony supplies before the war was China, which produced 13,312 tons per annum out of the total world output of 25,770 tons.[1] Production in the United Kingdom was about 6,000 tons a year against a normal consumption of 2,500 tons, while the price per ton in July, 1914, varied from £28 to £30.[2] Until 1915 the United Kingdom imported most of its ore from China and Australia, although a certain amount was drawn from Burma, Algeria, Spain and South Africa. The antimony refining industry in Great Britain had long been well established, the profits on the special brands of British antimony, which were well known in all the world markets, being very considerable. After the outbreak of war the position was altered. As a result of the urgent demand for antimony which was essential for shrapnel bullets and case shot fillings, and was used to some extent in the manufacture of ·303-in. small arms ammunition, only the richest ores, containing at least 50 per cent. of metal, were smelted. This practically restricted the sources of ore supplies to China and Bolivia.[3]

In January, 1915, there was a complete dislocation of the antimony market throughout the world owing to the conditions of Chinese production. The leading company engaged in the business of smelting and refining antimony was the Wah Chang (or Hua Ch'ang) Company of Changsha, closely connected with numerous mining companies, which held a Government monopoly of manufacture in and export from the province of Hunan. Owing to the cheap Chinese labour and abundance of material, antimony could be produced more cheaply in Hunan than anywhere else, and the industry had been allowed to lapse in other parts of the world, the Bolivian mines having been closed down. Under a pre-war agreement the Wah Chang Company had, until 1914, sold their whole output through a British firm, the New Chinese Antimony Company, at prices quoted on London markets, as published in the Daily Commercial Reports. After the outbreak of war, regular quotations ceased, but as the firm continued to quote prices some £20 lower than those prevailing in New York,[4] the Wah Chang Company closed down many of their works pending the settlement of a new agreement. The Chinese works had been much under German influence, and under the terms of the new agreement which was reached after considerable delay, the names of all purchasers

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[1] Sir L. Llewelyn's Papers, 11.
[2] Hist. Rec./R./600/17.
[3] Sir L. Llewelyn's Papers, 709.
[4] Sir L. Llewelyn's Papers, 11.

were to be disclosed to the British firm, who hoped by such means to check export to enemy countries. Owing, however, to the stimulus given by the war to production in Great Britain, it was unnecessary to import the refined antimony from China, and the bulk of the output from both China and Japan was despatched to Russia. Development was also carried on in other centres of production. The high prices paid for ore made it possible to re-open and work at a profit the rich mines of Bolivia, and America, thus provided with a convenient source of raw material, began smelting on a considerable scale.[1] Algerian deposits were developed during 1916; in the first half of 1917 Italy produced 2,768 tons of ore and in 1918 South Africa was making regular shipments.[2]

(*b*) CONTROL OF PRICES BY AGREEMENT.

In July, 1915, when the Ministry of Munitions became responsible for metals required in shell manufacture, immediate action was necessary to control the price and supply of antimony. The price had risen during the previous year from £30 to £125 per ton, and in July the Ministry called a meeting of the three leading British refiners with a view to securing steady supplies throughout the war at a reasonable price. The Government requirements for 1916 were estimated as follows :—

	Tons per month.
For shrapnel bullets	800
For ·303-in. ammunition	100
For trade purposes	100
Total	1,000

This 1,000 tons the British refiners could supply, provided that they could obtain the necessary ore, and an agreement was concluded by which the Department undertook to buy all their existing stocks at £100 per ton and their future output at a sliding scale, based on the purchase price of ore, while in order to keep the latter price as low as possible the firms agreed to purchase ore jointly instead of competitively.[3] By the end of the year the remaining firms of smelters in the country were included in this agreement and the whole smelting capacity of the kingdom was thus placed under the control of the Department.[4] The result of this action was seen in the immediate drop in the price of ore from 14s. to 10s. per unit, so that in 1916 the price of antimony fell to £90 per ton. The capacity of the smelters was about 1,200 tons per month and an additional 200 tons was obtained under the Penarroya hard lead contract.[5] A maximum of 1,400 tons per month could, therefore, be obtained, and as the British munitions requirements were only 800–900 tons any surplus was to be available for Russia and Canada, or for trade purposes.[6]

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[1] Sir L. Llewelyn's Papers, 11 ; 111.
[2] *The Ironmonger, Metal Market Year Book*, 1918.
[3] HIST. REC./R./1850/1.
[4] (Printed) *Weekly Report*, No. 22, I (25/12/15).
[5] See above, p. 94. [6] HIST. REC./R./1850/1.

(c) Accumulation of Stocks.

Early in 1916 the French Government was able to offer antimony to the Allies,[1] and as the British refiners were able to secure sufficient ore to keep the works up to their full capacity, by May, 1916, there was a surplus for disposal,[2] while, owing to the decline in prices in America and Japan, imported metal cost £20 per ton less than the price agreed between the Department and the smelters.[3] In view of the exceedingly low price, considerable purchases of refined antimony were made from importers to increase the stock held in reserve,[4] more than 1,650 tons being bought by the Ministry between November, 1916, and February, 1917.[5] The smelters were, nevertheless, authorised to buy ore sufficient to keep their works at full capacity until June, 1917,[6] so that by the autumn of 1917 the Ministry stocks had reached 8,700 tons and reduction was necessary.[7] At the same time, to ease the shipping position, arrangements were made to restrict the smelting works to two-thirds of their full capacity.[8] In November and December further restrictions reduced them to one-half[9] and finally one-quarter of their capacity, in spite of some complaint from the smelters and the fact that the reduced rate of output would increase the cost of production, since stocks of ore already bought would then be sufficient to supply the smelters until October, 1918.[10]

On 9 March, 1917, antimony was included in the list of metals, speculation in which was prohibited by Regulation 30B of the Defence of the Realm Act.[11] The metal, together with its alloys and oxides or sulphides, was included in Group B of the export prohibitions list, as revised in May, 1917, and the restriction of output enforced during the autumn did not sufficiently reduce the accumulation of stocks. Hence, in November, the prohibition of the import of ore or metal without licence was considered, in order that the Ministry might place its surplus stocks on the market. As the usual price for the imported metal was £75 per ton, and the lowest price at which the Ministry could sell without loss was £85 to £91, the proposed action was for some time rejected as a dangerous precedent, but finally the order prohibiting import was issued in January, 1918, "in view of the saving of tonnage which would thus be effected." In November, 1917, the shrapnel requirements up to June, 1918, were estimated as 8,700 tons of antimony, while the metal in stock amounted to 9,176 tons, and sufficient ore had been bought to yield a further 5,150 tons.[12] In April and May, 1918, when demands arose for antimony oxides to be used by paint manufacturers as substitutes for lead and zinc, the smelters were instructed to manufacture a certain quantity of these.[13]

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[1] (Printed) *Weekly Report*, No. 26, I (22/1/16).
[2] *Ibid.*, No. 41, I (13/5/16).
[3] *Ibid.*, No. 47, IV (24/6/16).
[4] *Ibid.*, No. 67, IV (11/11/16).
[5] *Firms and Factories Lists.*
[6] (Printed) *Weekly Report*, No. 73, III (30/12/16).
[7] *Ibid.*, No. 115, III (27/10/17).
[8] *Ibid.*, No. 110, III (22/9/17).
[9] *Ibid.*, No. 117, III (10/11/17).
[10] *Ibid.*, No. 121, IVA (8/12/17).
[11] *The Ironmonger, Metal Market Year Book*, 1918.
[12] D.D.G.M. 1087.
[13] (Printed) *Weekly Report*, No. 137, IVA (13/4/18).

(*d*) THE PROPOSED CLOSING-DOWN OF SMELTING WORKS.

In July, 1918, in view of the increasing tonnage difficulties, the large stocks held by the Ministry, and the fact that both nickel and antimony could be bought more cheaply in America than they could be produced at home, the closing down of the works smelting antimony and nickel in Great Britain was considered. The question of nickel was dependent upon the available supply of oxides and was still unsettled at the date of the Armistice,[1] but the case of the antimony smelters was more clearly defined. The financial saving apparently to be achieved by purchase abroad was in itself by no means assured. The Chinese works were closing down, and if British smelters also stopped the Americans would be left alone in the market, a fact which would undoubtedly raise the price, while that country's peculiar advantages as to raw material, which were due to war conditions, would be lost after the war and production become more costly. Antimony smelting was a long established industry in England, and the Government was under a certain moral obligation to the smelters in return for their support during the first two years of the war. To keep the works in operation a minimum quantity of 5,000 to 6,000 tons of ore was required, as contrasted with a pre-war import of 10,000 tons, or the 1916 figure of 31,220 tons, and as about half this tonnage would be required if American metal was imported instead, the saving in shipping space would be negligible. A sub-committee of the Committee of Reconstruction, after considering the plant necessary to an important post-war industry, recommended that the Government stocks should be liquidated only in consultation with the trade to avoid endangering the stability of the market. Accordingly, at a conference held in August, 1918, it was decided to maintain the smelting industry for the next six months.[2]

(*e*) THE POSITION IN NOVEMBER, 1918.

At the end of August the increased shrapnel programme seemed likely to exhaust the stocks by the end of the year.[3] In the following month additional imports of ore at the rate of 2,200 tons per month for the four months, September to December, were consequently secured,[4] and at the end of November stocks were as follows :—[5]

	Tons.
In Ministry Store	3,000
Ore in transit, or at works equivalent to	1,500
To be received from Bolivia	5,000
Returned from Russia	750
	10,250

[1] See below, p. 132.
[2] Sir L. Llewelyn's Papers, 709.
[3] (Printed) *Weekly Report*, No. 157, IVA (31/8/18).
[4] *Ibid.*, No. 158, IVA (7/9/18).
[5] *Ibid.*, No. 168, IVA (16/11/18).

Antimony was immediately transferred to Group C of the Exports Prohibitions List,[1] and the Government arranged to release metal without special priority permits and at fixed prices for general industrial purposes. The outlook for the smelters was serious, as the peace time consumption of antimony is small, although it is essential for type metal and anti-friction alloys, and a long time would have to elapse before Government stocks could be absorbed. During the war Japan had increased her production to seven times her former capacity, and China to four times, while the British refining capacity had been more than doubled, and a world surplus of production was inevitable.[2]

II. Bismuth.

The pre-war production of bismuth was rather less than 500 tons per annum, of which 300 tons were produced in Bolivia, 150 tons in the United States and Mexico, and the rest chiefly in South America (exclusive of Bolivia) and Australia, while small quantities of ore were also found in Scandinavia, Saxony, and Hungary. The Bolivian mines were controlled by a syndicate largely under German influence; the ore was refined in Germany, and large quantities of metal exported to England. After the outbreak of war the ore was diverted to England, and with some difficulty British refineries succeeded in producing adequate quantities of metal.[3]

Before 1918 little difficulty was experienced in meeting British requirements, which amounted to some 180 tons per annum, of which 140 tons were utilised in the form of bismuth salts for medical purposes, and the remainder for the production of white metals for bearings and other industrial purposes. The demands for medical use were very much increased during the war, as bismuth was largely employed in the treatment of dysentery and similar diseases, but the requirements for industrial purposes remained small until the end of 1917, when makers of aero engines used it to a considerable extent.[4]

London served as the world market for bismuth throughout the war, as a London firm, Messrs. Grossmith & Lubolt, the selling agents to the Bolivian syndicate, dealt with all Bolivian ore, and Messrs. Avelino Aramayo & Company, had almost a monopoly of refining. The Bolivian ore imported amounted to about 300 tons per annum, as compared with some 82 tons imported from all other sources, but in spite of the advantage afforded to the firm by this position, the price was only raised from 9s. per lb. (pre-war value) to 11s. in 1917, and did not exceed 12s. 6d. per lb. in 1918.[5] All arrangements for supplies to British consumers were arranged through Messrs. Aramayo & Company and Johnson, Matthey & Company, the refiners of Australian ore,[6] and except for a purchase made on behalf of Russia and two very small lots in 1918, the Ministry made no direct purchases.[7] In 1917, deposits were opened up in South Africa, and although by

[1] (Printed) *Weekly Report*, No. 169, IV.A (23/11/18).
[2] HIST. REC./R./600/17.
[3] C.R. 4510.
[4] (Printed) *Weekly Report*, No. 124, IVA (3/1/18).
[5] M.C. 563.
[6] C.R.V./S./829.
[7] *Firms and Factories List.*

1918 shipments were not large,[1] it was hoped that this supply might be developed to counter-balance the restoration of German influence in Bolivia possible after the war.[2] The export of bismuth ore from Australia was controlled by the Commonwealth Government, which was anxious to encourage the refining industry in Australia. Pending the completion of these works permits were issued for the export of ore, and in January, 1918, 20 tons of ore per month were received in Great Britain, a quantity equal to about 50 tons of refined metal in the year.[3]

On 12 March, 1918, the Ministry issued an Order including bismuth ores, metals and salts in the list of materials of which the sale was controlled by Regulation 30A of the Defence of the Realm Act, and requiring returns to be made of all stocks in hand, whether with producers, dealers or consumers, of the monthly output and deliveries from mines, and the shipments received or in transit, except where these were less than certain specified quantities. At the same time a general permit was issued allowing the purchase of quantities not exceeding 10 lbs. of metal or 56 lbs. of salts per month for pharmaceutical or medical purposes.[4] From the returns received under this Order the position appeared quite satisfactory, and no difficulties arose in connection with the Order.[5] The supplies remained adequate throughout the summer and the Ministry was prepared, if necessary, to permit export to Denmark to prevent that country's exporting fats to Germany in return for supplies of chemicals and metal.[6] The Ministry had no considerable stocks on its hands at the date of the Armistice, and as no immediate change in the medical requirements was probable while considerable numbers of troops remained in hot climates, the National Health Insurance Commission requested the Ministry to retain control.[7]

III. Chrome Ore.

The British requirements of chrome ore increased very largely after the outbreak of war. The most important demand was for the production of ferro-chrome, an essential element of the special steels required for armour-piercing shells and armour plate, the demand being augmented in 1917–18 by the needs of aeroplane and tank construction. Again, large quantities of ore were used by the chemical trade for the production of khaki dye and in tanning processes, and thus by the end of 1917 practically all the ore imported was consumed for war purposes.[8]

(*a*) Sources of Supply.

The mines forming the chief sources of supply lay in Rhodesia, Northern India and Baluchistan, New Caledonia and Greece, and the world's production in 1913 was approximately 130,000 tons.[9] Of this

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[1] C.R.V./A./302. [2] C.R. 4510. [3] C.R.V./A./8.
[4] *War Material Supplies Manual* (31/5/18).
[5] (Printed) *Weekly Report*, No. 135, IVa (30/3/18).
[6] C.R.V./D./094. [7] (Printed) *Weekly Report*, No. 175, I (11/1/19).
[8] D.D.G.M. 1411, 1412. [9] Hist. Rec./R./600/17.

output the greater part was controlled by a British firm, the Chrome Company, Ltd., and in 1914–15 no difficulty was experienced in meeting the British requirements from the mines of India and Rhodesia. A small regular supply of ore for furnace linings was drawn from the Shetland Isles,[1] while owing to the increased demands which followed the outbreak of war several abandoned chrome mines in Norway were reopened to supply Norwegian ferro-chrome works which had the advantage of cheap water-power.[2]

In 1915 the only British firm regularly making ferro-chrome was the Newcastle Alloy Company, whose production was some 40 tons weekly,[3] and a large proportion of the ore imported into England was sent on to Norway for treatment and returned as ferro-chrome, while the particular grade of low carbon ferro-chrome needed for high-speed tool steel was made in France.[4] In 1916 the British Government requisitioned 12,000 tons of chrome ore for the French firms and promised assistance in the matter of shipping, in return for the promise of regular monthly deliveries of ferro-chrome.[5]

(*b*) Relations with the Trade, 1915–1917.

The normal pre-war price for chrome ore was about 55s. per ton, according to its percentage of chromium, usually 40–50 per cent., occasionally more.[6] In January, 1916, the price had risen to about 140s. per ton, but as the trade did not anticipate any difficulty in increasing supply if necessary, the Ministry exercised no control over the ore until 1917.[7] The Raw Materials Department maintained close contact with the ferro-chrome manufacturers and chemical firms, and applications were constantly made to it for assistance in the matter of transport or information as to sources of supply and the requirements of the trade. Repeated offers were made to the Department from firms anxious to sell direct to the Ministry, but the Ministry refused to enter into the market.

(*c*) Transport Difficulties.

In the late spring of 1917, owing to the shortage of shipping, transport from India and Australia became difficult, and from this time on the question of transport became more and more difficult, and in 1917–1918 formed the vital factor in the matter of supply.

Tonnage was allocated by the Shipping Priority Committee largely in accordance with the recommendation of the Raw Materials Department, and thus, before any definite order to restrict dealings in ore was issued, in practice a very considerable share of control was taken by the Department. Occasionally, shippers were able to obtain transport without assistance, but normally the Ministry was requested to urge priority on the ground that chrome ore was essential to armament

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[1] D.D.G.M. 1011.
[2] *The Ironmonger, Metal Market Year Book.*
[3] Sir Leonard Llewelyn's Papers, 2.
[4] D.D.G.M. 1011.
[5] C.R.V./F./188.
[6] Hist. Rec./R./600/17.
[7] D.D.G.M. 1413.

production. As the shortage of ferro-chrome became more acute, the Department ceased to recommend the allocation of any tonnage to low-grade ores containing less than about 47 per cent. chromium, which had formerly been used for steel furnace linings, as it was considered that a substitute could be used for this purpose.[1] Imports were thus reserved for ferro-chrome works and chemical purposes.

In May, 1917, iron containing chrome was placed in Group A of the Exports Prohibition List, while chrome ore was included in Group B, i.e., of goods of which export was prohibited without permit to all destinations other than British possessions.[2]

In view of the common interests of the Allies in the development of metal production, a series of inter-Allied conferences was held to secure united action. The first of these was called in August, 1917, to discuss the development of chrome ore mines, the division of ore among the Allies, and the importance of providing adequate tonnage. Subsequent conferences on the subject maintained close co-operation between the British and French Governments,[3] thus, when in September, 1917, it was found that offers for Greek ore were being made simultaneously from both countries, the British orders were at once withdrawn to avoid competition.[4]

During 1917, the supplies of high grade ore for chemical work which had formerly been imported from New Caledonia were gradually replaced by increased quantities from India, and after the autumn of this year New Caledonian ore was no longer imported. The two centres of production during the critical period of supply were thus Rhodesia, using Beira as a loading port, and North India, which shipped from Karachi or occasionally Madras, but since all the mines were situated a long distance inland, in addition to shipping questions further difficulties arose in transport to the coast. In May, 1917, considerable relief was afforded by the construction of a new length of track to connect up the Indian mines with Karachi.[5] In August, much trouble was experienced in maintaining adequate stocks of ore at Beira to absorb the tonnage allocated by the Shipping Committee, owing partly to shortage of rolling stock, particularly of locomotives, on the Rhodesian railways, and partly to the fact that other goods were given priority.[6] The allotted shipping space at Beira amounted at this date to 3,500 tons per month, but from July to November monthly deliveries in England only averaged 2,000 tons, and by December the total amount in arrears was 7,850 tons.[7] In November, after urgent appeals had been made to the Government, additions were made to the rolling stock on the Rhodesian railway, and a conference was called to settle priority questions.[8] These measures effected an improvement as regards railway traffic by the spring of 1918, but in the meantime, in the course of 1917, supplies in England had run very short.

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[1] D.D.G.M. 1413.
[2] *The Ironmonger, Metal Market Year Book.*
[3] D.M.R.S. 510.
[4] D.D.G.M. 1412.
[5] D.D.G.M. 1413.
[6] D.D.G.M. 1044.
[7] D.D.G.M. 1412.
[8] D.D.G.M. 1044.

(*d*) CONTROL OF DEALINGS IN CHROME ORE.

Although the Government continued to stand out of the market, Messrs. Chalas & Sons (the agents of the Chrome Company) had been requested by the Raw Materials Department, in May, 1917, to reserve their stock and the deliveries they were expecting for disposal in accordance with the Ministry's instructions, and in July the ore was allocated to different firms holding definite orders, by Messrs. Chalas, under arrangement with the Ministry.[1]

In August, when the shortage had become very acute, definite control of all dealings in chrome ore was taken over by the Ministry. Under the Defence of the Realm Regulations an Order was issued on 31 August, 1917, prohibiting the purchase, sale or delivery of ore without permit from the Ministry.[2] For some months the situation remained very critical. In August the Newcastle Alloy Company had only sufficient ore for the production of 1,000 tons of ferro-chrome, while their commitments already reached about 1,600 tons. To meet their obligations 1,000–1,500 tons more ore was required in September.[3] In October some of the Norwegian works were at a standstill for lack of ore and others in England which had begun producing ferro-chrome in 1917, were barely kept open, and English steel works were consequently delayed. Throughout the year, however, there was no shortage of ore at the mines, the whole difficulty being that of freight. The shipping allocation during the latter half of 1917 was raised from 4,500–6,000 tons per month, normally divided into 3,000–3,500 tons from Beira and the rest from Karachi. The actual shipments received were as follows :—

1917.	*From Beira.* Tons.	*From Karachi.* Tons.
July	2,200	1,500
August	1,000	1,120
September	2,800	1,025
October	1,000	—
November	1,200	5,512
December	2,200	2,794 and 540 from Madras.

In November the Department entered upon the only direct contract for ore which it placed, buying 500 tons at the prevailing price of £10 10s.[4] Early in 1918 the monthly requirements of ore were estimated at 4,600 tons from January to June, and 5,400 tons from July to December, as compared with an average consumption in 1917 of 3,000 tons.[5] The total supplies received during the first five months were 7,010 tons from Beira and 6,120 from India. In February the situation was critical and the whole aeroplane programme was in danger of being held up for want of special steels. Shipping had been suspended in February and March both from Africa and India and the Newcastle Alloy Company urged that immediate shipments must be made if they were to arrive

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[1] D.D.G.M. 1413. [2] HIST. REC./R./680/1. [3] D.D.G.M. 1413.
[4] D.D.G.M. 1412. [5] *Ibid.*

before existing stocks were exhausted. In April 2,650 tons were shipped and the following month showed considerable improvement. Meanwhile development was being carried out in the Shetland Isles and it was hoped to produce about 100 tons per month during 1918. The Newcastle Alloy Company had extended their works and hoped by August to be able to produce 600 tons of ferro-chrome monthly which would make the country independent of Norwegian supplies.[1] In June it was found that the demands for the aeroplane programme were less than had been anticipated but there were new requirements for tank construction.[2] Shipments came forward more satisfactorily during the summer of 1918, and although the full demands were rarely met the average monthly delivery from June to October was 4,610 tons. The difficulty lay chiefly in the irregularity of shipments since the ferro-chrome works had only a limited capacity, and, as the Government had no arrangements for buying and storing stocks, a particularly large cargo such as arrived at the end of July could not be kept to balance a future shortage, but had to be transhipped to France.[3]

(*e*) The Position after the Armistice.

After the Armistice the demand for ferro-chrome fell to a certain extent, but the trade had only small stocks, while the Ministry, having disposed in May of its only purchase had no stocks at all on its hands.[4] It was thought that the stocks in the hands of ferro-chrome makers would probably be easily absorbed by steel works, since, as no ore for furnace linings had been imported for a long time, there was a large demand for it. The effect of the war-time demands had been to develop a ferro-chrome industry in England which could reasonably be expected to compete with Scandinavian firms, and therefore, the demand for ore, though appreciably lessened by the cessation of hostilities, was not likely to fall to the pre-war level.[5] The requirements of the chemical trade remained considerable, and the total post-war consumption was estimated at 3,000 tons per month.[6] The emergency arrangements for transhipping ore to France were brought to an end,[7] and on 17 December, 1918, the control order was suspended. In January, 1919, when the stocks at various works totalled about 3,000 tons no further control was required, although special arrangements for shipping from India and Rhodesia were necessary for some months.[8]

IV. Cobalt.

The quantities of cobalt used during the war were small, but regular supplies were of great importance as the metal was an essential alloying element in certain high-speed steels. Ferro-cobalt, containing 70 per cent. of cobalt, was the usual form in which it was added to steel, but

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[1] (Printed) *Weekly Report*, No. 143, IV (25/5/18).
[2] *Ibid*, No. 148, IV. (29/6/18); No. 153, IV (3/8/18).
[3] D.D.G.M. 1411.
[4] Hist. Rec./R./600/17; D.D.G.M. 1411.
[5] D.D.G.M. 1411.
[6] Hist. Rec./R./600/17.
[7] D.D.G.M. 1411.
[8] Hist. Rec./R./600/17.

proposals were made in 1916 to introduce it in the form of cobalt fluoride, which could be more cheaply prepared. Steels containing 4 per cent. of cobalt, in addition to tungsten and chromium, retained their edge well at or near red heat and would cut or turn manganese and nickel chrome steels.[1]

The metal was chiefly produced in Canada, Ontario being the principal centre, largely as a by-product from the silver ores mined in the Cobalt district. In 1915, Canadian production amounted to 211,610 lbs. of metal and 423,717 lbs. of cobalt oxide, while in 1916 these figures rose to 215,215 lbs. and 670,760 lbs. respectively. The ore was also found in Scandinavia, but in 1917 it was stated that no Swedish ore had been used for war purposes and the Norwegian mine at Snarrum was no longer worked.[2]

There was little difficulty in maintaining supply and no control was necessary beyond the inclusion of cobalt in Group B of the Exports Prohibition List[3] and in the list of metals affected by Regulation 30C of the Defence of the Realm Act. Its export was thus restricted to British possessions and its use in Great Britain was subject to the Ministry's control.[4]

V. Graphite.

The two chief sources of supply for graphite (sometimes inaccurately known as plumbago) were Ceylon and Madagascar, while small quantities were also mined in Italy and Korea. Graphite was essential to munitions production as it was used to make the crucibles for many of the great metal smelting furnaces of the country. It was also required in America for the manufacture of electrodes,[5] while small quantities were utilised in lubricating shells. The largest consumers of graphite crucibles were the casters of brass and copper or alloys, but they were also used in some steel furnaces. Adequate supplies of graphite were, therefore, essential to the output both of small arms ammunition and of shell.[6]

Many different grades of metal were on the market, giving a wide range of prices, but all of these rose abnormally during the war. The price of Madagascar graphite, which before the war was £45 per ton, rose to more than £130 in 1917[7] while metal from Ceylon varied between £20 and £120 according to its quality. The Madagascar graphite gave better results in crucible making than that from Ceylon, and was also easier to prepare so that shortly before the war the two leading crucible makers in England had installed new plant adapted to use only the former and had scrapped their old machinery. It was thus impossible for England and France to meet their requirements each from her respective colony, and the closest co-operation between the two Governments was essential. No shortage was felt until early in 1916, when the monthly requirements of British crucible makers were 1,450 tons and were steadily increasing. At the same date the demands for

[1] C.R.V./S./0222.
[2] *Ibid.*
[3] *The Ironmonger Metal Market Year Book*, 1918.
[4] *War Materials Supplies Manual* (28/2/18).
[5] See below, p. 159.
[6] D.D.G.M. 1296.
[7] D.D.G.M. 1034.

Ceylon metal (apart from 250 tons required for Russia) were from 800–1,000 tons a month, but this quantity would decrease as larger supplies became available from Madagascar. In 1916, however, exports from the French colony were barely equal to Allied demands, although production was much developed after the outbreak of war, the output from January to June, 1916, being 9,000 tons.[1]

The Ministry itself scarcely entered into the market—the sole direct purchase which it made was of 1 cwt. bought in May, 1918[2]—but it controlled importation and distribution. In May, 1916, all imports from Madagascar were consigned in accordance with the request of the French Government to a single firm, the Morgan Crucible Company, which became responsible for distribution among British consumers.[3] No metal was exported from Madagascar without licence from the French Government, which in the case of exports to British firms was only granted upon the application being endorsed by the Ministry with a certificate that it was required for war purposes.[4] In order to meet British and French requirements the French Government, in July, 1916, cancelled all existing licences for export to America on the understanding that supplies for that country would be made available from Ceylon, and agreed to submit all future applications to the British Ministry. Licences were sought to export two classes of graphite produced from the French mines, the high grade suitable for crucibles and the by-product obtained from their manufacture. Export of the former was usually prohibited in order to maintain allied stocks, but the latter had no market in Great Britain and was disposed of abroad.[5] By 1917, American purchases absorbed the bulk of the Ceylon supply, which had been greatly developed during the war, the exports to America being 13,300 tons in 1915 and 24,500 tons in 1916,[6] and in June definite steps were taken by the Ministry to control supplies from the island. The Colonial Office was requested to secure the prohibition of all exports of graphite except under permit from London, and the appointment of a local advisory committee which should be also authorised to arrange purchases and regulate prices every quarter. At the same time the British Mission in America was to approach the United States Government with a view to the appointment of a responsible authority to deal with the question there.[7]

During 1917 shipping became increasingly difficult, and in December firms were requested to send in statements of their requirements to enable the Ministry to deal with the Shipping Priority Committee.[8] In January, 1918, the small supplies from Korea were stopped for lack of tonnage, and the requirements from Ceylon were correspondingly increased.[9] Freight from Madagascar was also difficult, and in 1917 British importers were practically dependent on boats released by the Admiralty ; as this involved carrying a minimum of 1,500 tons in one bottom the sinking of any one ship had a serious effect on British stocks.[10]

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[1] D.D.G.M. 1296. [2] *Firms and Factories List.* [3] D.D.G.M. 1260.
[4] B.M.2/518. [5] D.D.G.M. 1260. [6] D.D.G.M. 1295.
[7] (Printed) *Weekly Report*, No. 98, III (30/6/17).
[8] *Ibid.*, No 123, IVa (29/12/17).
[9] *Ibid.*, No. 151, IVa (20/7/18). [10] D.D.G.M. 1295.

In spite of difficulties the position of graphite supplies never became really critical, and in August, 1918, the Morgan Crucible Company advised that, owing to the collapse of Russia and the development of French manufacture of crucibles (resulting in the prohibition of imports of British crucibles), the British demand for graphite had greatly diminished, and the existing accumulation of stocks rendered further shipments from Madagascar unnecessary for months to come.[1]

VI. Nickel.

Nickel was required during the war mainly for three classes of manufacturers whose output was absorbed for munitions purposes. These were the makers of armour plate, chiefly for the Admiralty, of internal combustion engines and of cupro-nickel strip for small arms ammunition bullets. Of these three the nickel-steel works consumed about two-thirds of the total supplies while a certain proportion was also used for electrical works, metal plating and coins.

(*a*) Sources of Supply.

In the year 1913–14 the total world's production was about 30,000 tons,[2] of which approximately two-thirds was produced from Canadian and most of the other third from New Caledonian ore, a small quantity only being obtained as a by-product from copper refining in America. Great Britain and France between them thus controlled some 90–95 per cent of the world's supply of ore,[3] but until 1918 no refining was carried out in Canada and the fact that the nickel itself in its commercial form was produced largely in America subsequently complicated the question of control. Some 5,000 tons were refined each year in Great Britain by the Mond Nickel Company, the Anglo-French Nickel Works and Messrs. Henry Wiggin and Company. Before the war the Admiralty, as the largest consumers of armour-plate, had a standing agreement with the Steel Manufacturers Nickel Syndicate and the Société Anonyme le Nickel which dealt in New Caledonian ore, whereby each of the five firms in the Syndicate undertook to maintain a stock equal to a year's requirements, and the Société Anonyme a stock equal to the total requirements of the firms. This agreement was continued in 1914 for seven years, and whereas the five firms normally held a total of 1,100 tons, in June, 1915, they held 2,474 tons and the Société 5,475 tons. The British consumption from August, 1914–July, 1915, was 8,497 tons, and production amounted to 9,705 tons, while 1,925 tons were imported from America. On the formation of the Ministry, therefore, the position as regards nickel was satisfactory, the only apparent effect of the war being an increase of price from £160 to £175 per ton.[4]

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[1] (Printed) *Weekly Report*, No. 153, IV.A (3.8.18); D.D.G.M. 1260.
[2] Sir Leonard Llewelyn's Papers, 8.
[3] C.R.V./C./052.
[4] Sir Leonard Llewelyn's Papers, 8.

In September, 1915, a Royal Commission was appointed to investigate the nickel resources of Ontario, and reported that the proven ore of that area could be conservatively reckoned at 70,000,000 tons, while the probable and possible supplies would raise the figure to 150,000,000. No such vast deposits were known in any other country, and competition with Canadian producers was impossible.[1]

(*b*) Supplies to the Allies.

In the same month applications were made by the Allies, and particularly by Russia, to the British Government for nickel,[2] and from this time the Ministry acted practically as a buying agent for the Russian Government. By this method the Russians effected a considerable economy, as the British Government buying price was £175 per ton against the current market price of £225 which Russia had previously paid. Smaller quantities were also supplied from time to time to the other Allies.

The requirements for 1916 were estimated in February as follows :—

Tons	
3,391	for home consumption.
2,000	for Russia.
500	for Japan.
500	for Italy.

No difficulty was anticipated in securing these quantities, and the principal aim of the Ministry in connection with nickel supply was to prevent any of the nickel product from ore mined in British territory from being supplied to Germany.

(*c*) Restriction of Supplies to Germany.

Norway and America were large exporters to Germany. The Kristiansand Nickel Refinery, of Norway, had sold under a long contract the whole of their production, amounting to some 100 tons monthly to Germany, and on 25 August, 1915, a meeting was held in London to discuss the possibility of cutting off this supply. An agreement had been drawn up to compensate the company in the event of their reducing their output, as was permissible under the German agreement, and the company agreed in addition to work for the prohibition of export. This latter step, however, would be useless unless export of nickel steel were also prohibited, and the Ministry wished to place sufficient orders in Norway to use up their supply of nickel.[3] Hence in December, 1915, the Ministry agreed to buy from Norway a quantity not exceeding 1,500 tons a month of nickel steel containing about 5 per cent. of nickel and 500 tons of cupro-nickel, while it also considered placing contracts for rich iron and nickel alloys although at prices higher than those charged by British firms.[4]

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[1] *The Ironmonger Metal Market Year Book.*
[2] (Printed) *Weekly Report*, No. 9, I. (25/9/15).
[3] Sir L. Llewelyn's Papers, 8.
[4] A.M.2/155.

The American firms smelting Canadian ore were (with the exception of the American Smelting and Refining Company) organised in a ring, which sold through the agency of Messrs. Henry R. Merton & Sons and usually worked in co-operation with the British Government. The Admiralty had arranged to take 50 tons per month from the American Smelting and Refining Company—nearly their whole output—throughout the war.[1] The largest producers were the International Nickel Company or Huronian Company, but as their ore was mined in Canada the British Government was able to exercise a certain control over its sales. The Canadian Government kept a representative at the Company's works to ensure that nickel was only supplied to approved consignees, and the company undertook that no nickel should be exported to enemy countries.[2] In September, 1916, the Ministry suggested that the French Government should exercise a similar control over the United States Nickel Company, which refined New Caledonian ore, and in January, 1917, this control was vested in the French Military Mission at New York.[3] Early in 1916, considerable agitation had arisen in Canada over stocks of nickel which were shipped to Germany by the submarine "Deutchland." Messrs. Merton, as a neutral firm acting for the whole ring of refiners and presumably cognisant of all deals, were regarded with increasing disfavour, both in Canada and Great Britain, although no definite charge was established against them. From the spring of 1916 arrangements were made to purchase British supplies through the Imperial Munitions Board, only one "spot lot" purchase being made through Messrs. Merton in November. Subsequently, the Imperial Munitions Board bought for the other Allies as no effective inter-Allied organisation existed for that purpose.[4]

(*d*) PURCHASES BY THE MINISTRY OF MUNITIONS.

On 29 February, 1916, under Regulation 30 B of the Defence of the Realm Act, all speculation was prohibited in a number of metals, including nickel. During the spring, the Ministry began to place direct contracts for nickel, and from March a proportion of the British requirements were bought by the Ministry and supplied to specified firms, while other firms continued to contract for themselves in order to obtain exactly the same class of metal that they were accustomed to use in their work. Ministry contracts were placed directly with the Mond Nickel Company, the Anglo-French Nickel Company, and with the American Smelting and Refining Company and the Huronian Company through Messrs. Merton.[5] The nickel produced in England by the Mond and Anglo-French companies was of a higher quality than American metal, and was used for cupro-nickel strip for small arms ammunition. In 1914 and 1915, very few firms had made this alloy, but in 1916, when the demand for the manufacture of ·303 ammunition considerably increased,[6] the Ministry encouraged

[1] Sir L. Llewelyn's Papers, 8.
[2] C.R.V./C./044.
[3] C.R.V./C./09.
[4] C.R.V./C./071
[5] A.M.2/425.
[6] (Printed) *Weekly Report*, No. 20, I (11/12/15).

its manufacture by the issue of the necessary proportions (i.e., 4 : 1) of copper and nickel.[1] Towards the end of the year, there were indications that the supply of Mond metal would be inadequate in 1917, the requirements being estimated at 7,809 tons, including 2,519 tons for small arms ammunition.[2] The Canadian Mines and Smelting works of the Mond Company could produce 50 per cent. more metal than it was possible to treat at the Welsh refining works, which the company had been unable to extend owing to difficulties as to plant and labour.[3] In consequence, economy of Mond nickel was essential. Woolwich Arsenal, which had formerly used Mond metal only, at the rate of 20 to 25 tons per week, arranged to substitute a quantity of American nickel,[4] while in November, 1916, arrangements were made for the steel manufacturers to use only American nickel, leaving the whole supply of Mond metal for cartridges. It was hoped that experimental work would enable a certain proportion of the American metal to be used as well for cartridge strip.[5] On 9 March, 1917, an order was issued under the Defence of the Realm Act requiring returns of all stocks of cupro-nickel strip in the country and prohibiting all dealings in it without permit from the Raw Materials Department of the Ministry,[6] while in May nickel was included in Group B. of the Export Prohibitions List. The returns made under the Order showed that there were approximately 3,100 tons in stock, of which 1,000 tons were held at Woolwich, and the rest was bought up by the Ministry.[7]

(*e*) TRANSPORT DIFFICULTIES.

Throughout 1917, the Ministry placed constant and increasingly large contracts with the Mond Company, and by July the freight difficulty in shipping ore from the various sources of supply had begun to cause considerable anxiety.[8] Requirements for 1918 reached 1,850 tons per month, as additional demands were made for aircraft construction and for mechanical transport.[9] Shipments from New Caledonia became impossible and were at first replaced by ore from Greece,[10] but in August, 1918, it was decided that as the nickel ore from that country was imported at the expense of iron ore from Spain, tonnage should no longer be afforded.[11] As a result of these constant difficulties, the two English refining works at Erdington and Swansea were only able to produce about a quarter of the full output. They succeeded in keeping the plant in operation while the various possibilities of importing ore or oxides were considered, and the question was still unsettled at the date of the Armistice.[12]

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[1] HIST. REC./R./1850/7. [2] *Ibid.*
[3] Sir L. Llewelyn's Papers, 8.
[4] (Printed) *Weekly Report*, No. 62, IV (7/10/16).
[5] *Ibid.*, No. 67, IV (11/11/16).
[6] HIST. REC./R./1850/7. [7] *Ibid.*
[8] (Printed) *Weekly Reports*, No. 103, II. (4/8/17).
[9] *Ibid.*, No. 130, IV. (16/2/18).
[10] *Ibid.*, No. 105, III (18/8/17) ; No. 107, III (1/9/17) ; No. 133, IV (9/3/18).
[11] *Ibid.*, No. 153, IVA (3/8/18).
[12] Sir L. Llewelyn's Papers, 8.

(*f*) POSITION AFTER THE ARMISTICE.

The first step taken towards decontrol was the transference of nickel to Class C of the Exports Prohibitions List,[1] and negotiations were entered into by the Ministry for the cancellation of outstanding contracts. The British consumption in 1918 was 13,212 tons,[2] and in the week following the Armistice the Ministry held stocks of 1,050 tons in Great Britain, and 2,300 tons in America. The International Nickel Company was 1,500 tons in arrears on its contract, and in December this amount was cancelled, although deliveries continued to be made under some contracts until the following year.[3] In January, 1919, the Government held stocks of over 2,000 tons, and gave notice that it was prepared to release these for general industrial purposes without special priority permits until the existing control orders were suspended. The Canadian output had been nearly doubled during the war, and now exceeded the pre-war consumption of the whole world. A surplus production seemed probable,[4] and it was suggested that nickel, together with certain other metals, might be sold to Germany. The matter was referred to the Treasury, and sanction to dispose of surplus stocks to Germany and Austria, on certain conditions, was obtained on 15 October, 1919. There was some difficulty in negotiating the sale, however, and the whole Government stock of nickel was eventually sold to a group of nickel firms (the Mond Nickel Company, the Anglo-French Nickel Company, Ltd., and the Société Anonyme Le Nickel) in March, 1920.[5]

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[1] (Printed) *Weekly Report*, No. 169, IVA (23/11/18).
[2] HIST. REC./R./600/17.
[3] *Ibid.*
[4] *Ibid.*
[5] Minutes of Raw Materials Committee *passim.* (HIST. REC./R./264.2/7.)

CHAPTER X.

MINERAL OILS.

I. Introductory.

Until the beginning of this century the various products of petroleum were in demand almost solely for lighting and lubricating, but the development of the internal combustion engine and the discovery, about 1898, of oils in Borneo and Texas, specially adapted for fuel purposes, changed the aspect of the situation, and at the outbreak of the war petroleum products were fast becoming prime necessaries of industry, and of land, sea, and air locomotion. Throughout the war large quantities of petrol were essential for motor traction and aircraft, while as the installation of internal combustion oil engines in ships proceeded a supply of fuel oil suitable for their use was increasingly required.

With regard to petroleum, Great Britain was not in the same favourable position as she was with regard to coal.[1] The British Empire had to rely almost entirely on supplies of petroleum drawn from foreign countries—e.g., the United States, Mexico, and the Dutch East Indies—and even the development of her own limited resources in Egypt, Sarawak, and Trinidad, were dependent, to some extent, on foreign, or quasi-foreign concerns. Some supplies were also obtainable from oilfields in Burmah, but the distance of these oilfields from Great Britain made import difficult, and this was also true in the case of Persian oilfields, over which Great Britain possessed influence. France and Italy, like Great Britain, had to rely almost entirely on imports. Of other powers, Russia possessed rich oilfields in the Caucasus, the United States had ample supplies within their own territories—being, indeed, the largest single producer of oil in the world—while Germany, through the Deutsche Bank, had obtained the monopoly of practically all the oil in Hungary, and controlled large supplies in Roumania.

The crude petroleum oil obtained in the oilfields is a mixture of a very large number of hydrocarbons of very different degrees of volatility, and it is in general separated by various processes of distillation, etc., into the following seven main groups of commercial products :—(1) petroleum ethers ; (2) naphthas, benzines,[2] petroleum spirits, or "petrols" ; (3) illuminating oils, burning oils, or kerosenes ; (4) intermediate, or gas oils ; (5) lubricating oils ; (6) residual oils, known as "residium" in America, and as "ostatki" (dregs) in Russia ; (7) paraffin-wax—where present in the crude oil. The "petrol" used

[1] C.R. 4523.

[2] Benzine is a commercial name of petroleum spirit. Benzene is the chemical name of a family of compounds obtained commercially as by-products in coal-gas manufacture.

in light oil engines is thus among the lighter petroleum products, while for use as liquid fuel on ships, i.e., both for burning under boilers and in internal combustion engines, heavier oils are used. The oils used in heavy oil engines, such as the Diesel engine, must, however, be purer than those required for burning under boilers. Nearly all burning oils consist mainly of members of the chemical paraffin series, these preponderating in American kerosenes, and being usually present in a somewhat less degree in Russian burning oils, but the term "paraffin oils" is reserved in commerce for the burning oils obtained from oil shale. Oil shales occur in many countries, including Great Britain, and in the latter half of the 19th century a Scotch shale industry was inaugurated, when it was discovered (in 1850) that by the slow distillation of bituminous coal and oil shale "paraffin oil" could be obtained. Crude shale oil resembles in many of its qualities petroleum obtained direct from oil wells, and, like it, consists principally of members of the paraffin oil and olefine series. The commercial products obtained from Scotch shale oil are similar to those obtained from the crude petroleums of the oil wells.

A supply of petroleum products was a vital necessity for the conduct of the war, for large quantities of fuel oil and petrol were required by the navy and by the army and air service respectively; petrol and lubricating oil were required in the manufacture of munitions; and petrol, kerosene, gas oil and lubricating oil were used in large quantities for industrial and commercial purposes.

At the outbreak of the war the petroleum trade in the United Kingdom was practically monopolised by two firms under foreign control—the Shell and the Standard. These two great oil groups had formerly been in competition, but since the beginning of 1911 they had apparently worked in concert, and from that date prices, which before had fluctuated, had been rising steadily. The Standard oil group was an American group and the Shell formed part of the Royal Dutch-Shell group, which consisted of the Shell Transport Company, a British company and the Royal Dutch Company, a Dutch concern, the latter having the predominant interest (60 per cent., as against 40 per cent.) in the subsidiary companies, so that the ultimate control of the great organisation was in foreign hands.

II. Early Efforts to Obtain Control of the British Oil Industry.

The use of oil engines for ships instead of steam engines made various economies possible[1]:—Using coal to generate steam, 1 ton of fuel could take 1 ton weight 60,000 miles; using oil to generate steam, 1 ton of fuel could take 1 ton weight 80,000 to 90,000 miles; using internal combustion oil engines, 1 ton of fuel could take 1 ton weight 150,000 to 200,000 miles. Hence a ship could travel far greater distances without need of replenishing her bunkers if fitted with internal combustion oil engines. Since oil fuel was therefore of vital importance to the British navy, the Admiralty urged that the

[1] These figures refer to ordinary commercial conditions and apply to the position existing in the middle of 1916. (C.R. 4524.)

Government must be in a position to direct the policy and control the output in one large oilfield, in order that the proportions of the various products to be refined from the crude oil might be determined in order to meet fuel oil requirements for the navy rather than the fluctuating commercial demands of the market for other oil products. Accordingly, in 1914, the British Government acquired a financial interest in the Anglo-Persian Oil Company, the remaining shares of this company being held by the Burmah Oil Company, which supplied the kerosene market in India.

The Admiralty regarded the maintenance of a strong independent group in India, Persia and Mesopotamia as a cardinal act of policy in order that the Government's position in bargaining for supplies from every quarter of the globe might be as strong as possible, and they were therefore opposed to the admission of any of the large cosmopolitan companies to these fields.

The Shell group were, however, anxious to strengthen their position in the East, and in the autumn of 1915, in connection with a proposed increase in the supply of toluol for high explosives (obtainable from the "straight run" fraction of Borneo petroleum), they put forward a scheme of amalgamation of the Burmah Company's interests with those of the Shell group, urging that increasing the "straight run" production would necessitate a corresponding increase in the amount of kerosene produced, and that if a market was to be found for this in India an arrangement with the Burmah Oil Company, who held the Indian market, would be imperative.[1] As an alternative, the Admiralty had proposed to get toluol from Persian oil by means of a "cracking" process (i.e., a process for producing toluol by destructive distillation from heavy oil); and Lord Moulton, in April, 1915, had authorised Admiral Slade and Sir Boverton Redwood, who at that time were the principal advisers of the Government on petroleum and its derivatives, to make arrangements for testing the process on a commercial scale in the plant of the Hall Motor Fuel Company at Thames Haven. Experiments had accordingly been carried out, but by the autumn of 1915 it was clear that though toluol could be so obtained the cost was prohibitive,[2] so that imports of Borneo petroleum had to be relied on. Before the end of the year it was found possible to make arrangements for supply from the Asiatic Petroleum Company (a member of the Shell group), which did not involve any amalgamation between that company and the Burmah Company.

About this time—i.e., in October, 1915—action had to be taken with regard to the British Petroleum Company, which acted as selling agents for the Shell benzine, under an agreement which was due to terminate in January, 1917, and for oil products of other producers who before the war were all German or controlled by German interests. Practically all the shares of this company were held by the European Petroleum Union, which was controlled by the Deutsche Bank. Its shares therefore were vested in the Public Trustee, and a temporary Board was nominated by the Board of Trade.

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[1] C.R. 4524. [2] D.F.3/P.A.C./8.

The whole question of future oil supply was far reaching and had an important bearing upon considerations of foreign policy. At this time an Inter-Departmental Oil Committee,[1] on which the Admiralty were represented, sat at the Colonial Office to deal with questions of oil exploration throughout the Empire, but mainly in the Crown Colonies.[2] There was, however, no single authority responsible for dealing with the whole question of oil supplies. In a letter to the Admiralty of 2 March, 1916, the Foreign Office urged that the whole attitude of His Majesty's Government towards the oil question should be reviewed at an early date. Leaving out of account supplies from America which were likely eventually to be entirely absorbed by the anticipated increase in the American demands, the principal sources of supply appeared to be those controlled by the Royal Dutch-Shell group, which had marketing rights current for several years in respect of various categories of oil produced by the Anglo-Persian and the Burmah Companies. It appeared desirable to examine whether this group could not be brought under British control by an amalgamation with these two companies or otherwise, and the Foreign Office accordingly suggested that a committee representing the several Departments concerned should be formed by the Board of Trade to examine what were the desiderata which the Government should aim at, with a view to definite action at an early date. In reply the Admiralty declared that they attached great importance to the maintenance of Government control of the Anglo-Persian Company, and advocated the strengthening of Government influence by the acquisition of a controlling interest in the Burmah company and a closer association between that company and the Anglo-Persian.

On 15 June, 1916, a meeting of the Inter-Departmental Oil Committee was held to discuss the policy of encouraging the establishment of oil fuel depôts owned by British firms on British and neutral territory. The Admiralty urged that since the Government had invested a large sum in the Anglo-Persian Oil Company the best policy appeared to be to develop the company as a fuel oil concern primarily, to provide fuel oil for the general trade in the East and on the Eastern routes. They stated that the company was quite ready to establish oil fuel installations at the principal coaling stations on the route from Great Britain to the Far East. A certain number of these had already been established in British India and others would be erected as soon as the sites could be obtained. To obtain satisfactory sites the good offices of the Government were required.

On 12 August, 1916, the Board of Trade put forward a scheme by which they hoped to obtain the control of the petroleum industry in the United Kingdom. On 24 August the Admiralty issued an alternative scheme, claiming that whereas under the Board of Trade scheme the Shell group in effect would absorb the British companies, one of which (the Anglo-Persian) was controlled by the British Government, under the Admiralty scheme the British companies would absorb the Shell. According to the latter scheme the Anglo-Persian Company

[1] C.R. 4524. [2] C.R.V./Gen./749.

were to acquire the undertaking of the Burmah Company, and a new company was to be formed under Government control to take over all the assets of the British Petroleum Company, with the object of acting as the distributing agents of oil products in the British Empire. It was estimated that the normal amount of oil products required by the United Kingdom per annum was 2,500,000 tons, and by the whole British Empire 5,000,000. The Admiralty were of opinion that sufficient oil for all requirements could be supplied from producers either British or British controlled. The Board of Trade, on the other hand, held that any combination to secure the oil supplies of the British Empire which did not include the Royal Dutch Shell group would be ineffective, and that the only practical course was to endeavour to bring about a combination including this group in which British interests should have the control. The essential conditions of such an arrangement were that there should be effective British control both as regards capital and in the actual management of the undertaking, that there should be complete security against any transfer of control to non-British interests, and that as the company or combination would be quasi-monopolistic, provision should be made to safeguard the interests of consumers. Inter-departmental negotiations lasted until October, when the Admiralty withdrew their opposition to the amalgamation of the Burmah Company with the Shell Company on the understanding that: (1) existing contracts between the Shell group and the Anglo-Persian Company should be remodelled; (2) a comprehensive arrangement should be entered into between the Burmah Shell Company and the Anglo-Persian Company on mutually satisfactory terms for bunkering business in the East, the market for all petroleum products of the Anglo-Persian Company west of Suez remaining free; (3) the Burmah shares in the Anglo-Persian Company should be vested in trustees, so that the new company should have no vote in the Anglo-Persian Company, and (4) the new British Petroleum Company should enter into such agreements as would safeguard the distribution of the products of the Anglo-Persian Oil Company.[1] The companies were subsequently amalgamated on these lines.

III. Organisations Concerned with the Supply and Control of Mineral Oils.

(*a*) The Petrol Control Committee and the Petrol Control Department.

Although the prices of petroleum products gradually increased, no steps were taken to place restrictions on the use of any of them until the spring of 1916 when there were indications that the amount of petrol coming into the country was diminishing. On 29 February, 1916, a meeting was held to consider the supply of petrol, at which representatives of the Ministry of Munitions, the Admiralty, the War Office and the Board of Trade, were present.[1] It was estimated that

[1] C.R. 4524.

at least 340,000 tons per annum were required, i.e., about 120,000 tons for the War Office, 46,000 for the Admiralty, 35,000 for the Explosives Department of the Ministry of Munitions and 131,000 for commercial uses, so that an import of about 30,000 tons a month should be assured. This meeting was followed by a preliminary inter-departmental conference on petrol control on 25 March, 1916,[1] at which it was agreed that executive action ought to be taken forthwith to ensure adequate supplies of petrol for urgent Government and industrial requirements and to ensure a proper distribution of available supplies to the public.

It was proposed that a petrol authority should be set up as soon as possible by the President of the Board of Trade to act as purchasing authority for all Departments of Government and as the authority responsible for controlling the distributions to the public of the available surplus. The importance of strict economy in the use of petrol by Government Departments was discussed, it being stated that one Department, namely, the Admiralty—had already established a committee to deal with this question.

Following this conference, a Petrol Control Committee was appointed under the President of the Board of Trade towards the end of April, 1916, to control the supply and distribution of petrol and to consider the measures necessary in the national interest to ensure adequate supplies for the purposes of the war and essential needs, and with the above object to regulate the use of petrol for other purposes in the United Kingdom, during the period of the war, and, subject to the Board of Trade, to give executive effect to the measures decided upon.[2]

A preliminary report presented by this committee to the President of the Board of Trade on 12 May, 1916, recommended that a census should at once be taken of the consumption of petrol by the various classes of users. But while the census forms were being completed and tabulated, the shortage of petrol became very serious and it became necessary to take immediate steps to regulate distribution and restrict unnecessary consumption. This was done with the assistance of the six principal supply and distributing companies who formed themselves into a sub-committee and agreed to meet the requirements of petrol users in strict priority according to a list prepared by the Petrol Control Committee. In the preliminary report of 12 May, the Committee also pressed for the release of two tank steamers for the importation of more petrol and in July two additional boats were allocated by the Admiralty for a period of three months. The situation, which had become critical at the end of July, 1916, then took a more favourable turn. Warnings to the motoring public to economise petrol and to avoid hoarding supplies were issued from time to time through the press, but these appeals were ineffectual. A census was taken on 20 June, 1916, under the powers provided by the Regulation 15A of the Defence of the Realm Act,[3] by the Census of Production Office of the Board of Trade. The collection and tabulation of the information received was completed by 20 July, and the figures then showed that the

[1] HIST. REC./R./1970/17.
[2] X.235/121, Second Report of the Petrol Control Committee.
[3] See Appendix IV.

estimated requirements for the civil population were 150,000,000 gals. of petrol per annum in addition to the needs of the Army and Navy. To meet the demands of the civil population, the petrol importing companies estimated that there would be available only 75,000,000 gals. and the situation had to be dealt with drastically. This was done by issuing licenses for the purchase of motor spirit. On 13 June, 1916, a proposal had been submitted to the Chancellor of the Exchequer for the imposition of a gallonage tax to be collected on all petrol licenses issued by the committee and he decided to adopt this new petrol duty in lieu of the contemplated increased duty on motor cars, limiting it, however, to owners of private motor vehicles. Provision was accordingly made under sections 15 and 16 of the Finance Act, 1916, for the issue of licenses for the purchase of motor spirit, to come into force on 1 August, 1916, and Motor Spirit Licenses Regulations were made by the Board of Trade,[1] a license duty of 6d. per gallon being imposed. The effect of rationing less essential services was to release a largely increased supply for those services which were essential, and in the first year of petrol licensing some 80,000,000 gals. were diverted from civilian to naval and military requirements.[2] As the demands of the air services and of munitions works and road transport generally increased and shipping facilities for importation decreased it became necessary to restrict the use of petrol still further, but since even the strictest economy would not enable the demand to be satisfied, it became necessary to develop additional supplies. Conservation of supplies was needed not only in the case of petrol but also in the case of other petroleum products. The Ministry of Munitions accordingly in May, 1916, suggested that the Petrol Control Committee should take over the control of all petroleum products and, finding that the Petrol Control Committee was not prepared at that time to do this itself, appointed a Committee for the Regulation of Petroleum Supplies,[3] and later formed a Munitions Petroleum Supplies Department.

Six months later, however, the Petrol Control Committee was prepared to reconsider its position. Its second report, issued on 19 December, 1916, contained the following passage :—

> " In view of the very close association of motor spirit with other petroleum products, some of which have been used in appreciable quantities as substitutes for motor spirit, and in consideration of the fact that the difficulties with which the Petroleum Supplies Committee of the Ministry of Munitions are faced are very similar to those with which the Petrol Control Committee have had to contend, we think it is advantageous in the national and commercial interests of the country that all these products (lamp oils, motor spirit, lubricating oils, gas oil and fuel oil) should now come under one control."

The report went on to state that though in May the Committee had been unable to add to their labours, they felt the experience they had gained in dealing with petrol questions would be valuable in approaching

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[1] See 2nd Report of Petrol Control Committee.
[2] HIST. REC./R./1970/10.
[3] See below, p. 141.

the similar problems connected with other petroleum products and were now prepared to undertake this work and to hold the balance between petrol and other petroleum products, and accordingly recommend that their terms of reference should be extended to include all products of petroleum.[1]

This proposed extension was not made, and in June, 1917, the Petrol Control Committee was reorganised, and its functions in connection with the issue of licenses and the rationing of petrol for civil and industrial needs were later transferred to a new Petrol Control Department of the Board of Trade, Sir Evan Jones being appointed its controller.[2]

Meanwhile, it had become necessary to refuse petrol licenses to private cars that were not used for business purposes or in the discharge of public duties, and further limitations were placed on supplies. An Order was issued by the Board of Trade on 6 February, 1917, making it compulsory for licensed dealers in motor spirit to give information when required as to the quantities of motor spirit supplied by them. On 9 March, 1917, the Petrol Control Committee announced that all substitutes for petrol which were sold for use in motor vehicles were to be entered on the motor spirit license held by the purchaser, and were to count as motor spirit. In May, 1917, a regulation (8GG of the Defence of the Realm Act)[3] was issued which aimed at preventing the consumption of petrol for pleasure purposes in hired cars, and in July, motor cars and taxi cabs were forbidden to attend race meetings. On 13 July, 1917, a second Order was issued with respect to information as to motor spirit, ordering licensed dealers to send particulars as to purchases, sales, deliveries, appropriations, and stock in hand to the Petrol Control Department. Another Order was issued on 11 October, 1917, under the Defence of the Realm Regulations, designed to put an end to the use of private cars for unnecessary purposes, as this still continued to an appreciable extent. The effect of the restrictions introduced during 1917 was to reduce the number of licenses from 306,000 to 231,000.[4] Towards the end of the year the practice of running motor car engines on coal gas instead of petrol was introduced, and as a result a Motor Spirit (Consolidation) and Gas Restriction Order was issued on 2 January, 1918,[5] followed by an amendment of the Order (6 February, 1918), as it applied to Ireland.

On 8 February, 1918, a Motor Spirit and Lamp Oil Order, fixing maximum retail prices, was issued by the Board of Trade, and a Motor Spirit Delivery Order followed on 26 February, forbidding delivery of motor spirit, unless the necessary vouchers were presented.

(*b*) THE COMMITTEE FOR THE REGULATION OF PETROLEUM SUPPLIES.

As has already been seen, in the summer of 1916 a Committee for the Regulation of Petroleum Supplies was appointed under the Ministry of Munitions. This committee held weekly meetings from

[1] X.235/121. [2] See below, p. 146. [3] See Appendix IV.
[4] HIST. REC./R./1970/11; *Times History of the War.* [5] See below, p. 156.

15 August, 1916. When it first met it decided to obtain the advice and assistance of importers, and an Advisory Committee of these importers was accordingly formed, to advise as to the necessity and probable effect of a reduction in the consumption of refined oil and gas oil. At a meeting of petroleum importers, held on 30 August, 1916, to discuss the formation of this Advisory Committee, it was agreed that the terms of reference should be :—

> "To consider and advise upon the probable effects of an arbitrary reduction in the supply of kerosene or gas oil to a certain quantity, and what the effect of reduction upon various classes of consumers would be, with the views of the Committee as to the necessity or the extent of any reductions."[1]

This Advisory Committee, having met on several occasions, presented a report to the general effect that, neutral tonnage being available in a larger quantity than was originally anticipated, the situation might be left to those interested in the market ; though, at the same time, the report made it clear that no guarantee could be given by the Committee that the adoption of such a course by the Government would be entirely satisfactory. This report was considered by the Committee for the Regulation of Petroleum Supplies to be inconclusive, leaving too much in a debatable condition, and to be, therefore, of very little use, save in so far as it emphasised the danger and difficulty of reducing supplies of kerosene on the existing basis of consumption.[2]

Since the question of supply was practically entirely one of tonnage, the desirability of collaborating with the Petrol Control Committee was apparent, and the necessity for co-operation was further emphasised by the fact that large quantities of kerosene were apparently being used as a substitute for petrol, in order to evade the restrictions on the latter product. This view coincided with that of the Admiralty, as expressed in a letter of 25 August :—

> "It appears essential that the question of the supply of Illuminating, Gas and Fuel Oils, should be dealt with in close association with that of Petrol, in order that the whole of the quantities for which tank tonnage is needed may be under review, and that the relative urgency of the various requirements may be considered."

The President of the Board of Trade also agreed that co-operation between the Committee for the Regulation of Petroleum Supplies and the Petrol Control Committee was advisable, but though the Chairman of the latter committee attended a meeting of the former on 20 September, and stated that in order to keep stocks at a constant level, 54,000 tons of petrol a month would require to be imported to cover the requirements of the Army and Navy, and requirements for munitions and general purposes, he was unwilling to give the committee any information which might result in the Admiralty withdrawing any tankers which had been furnished for the conveyance of petrol. The Committee for the Regulation of Petroleum Supplies were accordingly obliged to obtain from sources other than the Petrol

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[1] HIST. REC./R./1970/16. [2] HIST. REC./R./1970/17.

Control Committee, such information about petrol as was requisite for determining the proportions in which petroleum products should be imported. An interim report presented to the Minister of Munitions in October, 1916, gave a rough estimate of the necessary importations of various petroleum products (with the exception of fuel oil for the Admiralty) for the whole year 1916. The total amounted to 1,740,000 tons, being made up of 480,000 tons of kerosene, 240,000 tons of gas oil, 450,000 tons of lubricating oil, jelly and wax, and mineral colza, 108,000 tons of fuel oil, and 462,000 tons of petrol. The Committee recommended that the use of creosote, as a substitute for fuel oil, should be adopted as far as possible, and stated that special efforts would have to be made during the rest of the year if the importations of kerosene and gas oil were to satisfy demands and leave reasonable stocks in the country to safeguard requirements for the early part of the following year. This estimate, which gave the monthly requirements of petrol as 38,500 tons, was considerably lower than that given by the Chairman of the Petrol Control Committee, but as imports during 1915, when there were no restrictions on the use of petrol in force, were 480,000 tons, or 40,000 tons per month, it appeared likely that 38,500 tons was not an under estimate. It was therefore arranged that two ships formerly released for the conveyance of petrol should be used to convey kerosene for the British Petroleum Company, the organization of which company the Board of Trade desired to preserve.

The scarcity of tanker tonnage was becoming increasingly serious, and on 11 January, 1917, a scheme to secure adequate importation of petroleum products and proper economy of privately controlled tank steamer tonnage for the period of the war was put forward by the Committee for the Regulation of Petroleum Supplies.[1] In this scheme it was proposed (1) that the control and regulation of petroleum imports by the large importing companies should be assumed by the Government at once, (2) that as soon as possible an executive body should be formed on which all Government Departments then dealing or concerned in the question of petroleum supplies should be properly represented, and that this executive body should be responsible for the policy of the Government generally and should direct the action of the Petroleum Department, (3) that an Advisory Board, consisting of representatives of large oil undertakings together with one Government representative,[1] should be formed, which should be responsible for the proper division of permitted imports between the companies concerned, and (4) that, pending the formation of this executive body, the Petroleum Department of the Ministry of Munitions should act as the connecting link between all the Government Departments concerned and the trade Advisory Board, submitting all its actions in connection with this scheme to the Admiralty, the War Office, and the Board of Trade for approval.

Some of the suggestions put forward in this scheme were at once acted upon for the Munitions Petroleum Supplies Department (later superseded by the Munitions Mineral Oil Production Department) was

[1] C.R. 4526.

formed, an inter-Departmental Committee was appointed, and a Pool Board, which worked under the Board of Trade, was organised. Six months later, the responsibility for the production of fuel oil from home sources was handed over to the Ministry of Munitions, the Munitions Mineral Oil Production Department was formed, Mr. Walter Long's Petroleum Committee being set up about the same time.

These various organisations are described below.

(*c*) The Munitions Petroleum Supplies Department and the Petroleum Research Department.[1]

By February, 1917,[2] therefore, it had been found necessary to organise a Petroleum Supplies Department in the Ministry of Munitions owing to the great difficulty experienced by munition firms and essential industries in the country of obtaining supplies, first of lubricating oils, and ultimately, of burning oils, motor spirit, gas oil and fuel oils, including creosote. The branch, which was under the direction of Mr. Houghton Fry, was formed to deal with questions of the importation, home production and distribution of petroleum and similar mineral oils, and its efforts were continually directed towards maintaining sufficient supplies and seeing that the supply was so distributed as to secure an uninterrupted continuance of essential services. The staff and records of the Petroleum Section of the Munitions Overseas Transport Department were transferred to the new branch.[3] In cases where the work of the branch affected that of the Admiralty, War Office, Colonial Office, Board of Trade or other Government Department it was agreed that no action should be taken without the concurrence of the Department affected.

At the same time Sir Boverton Redwood was appointed Director of Petroleum Research, to organise research in connection with undeveloped sources of mineral oil in the British Isles. The Petroleum Research Department was at first a branch of the Munitions Petroleum Supplies Department, though later it came for a time under Admiralty control.

(*d*) The Inter-Departmental Petroleum Committee.

The quantities of petroleum products required by the Admiralty, the War Office, the Air Service, and the Ministry of Munitions constantly increased, and as the activity of German submarines began to make itself felt some co-ordination between the demands of the different Departments became imperative. At the beginning of 1917, the committees dealing with questions affecting the supply and distribution of petroleum were :—(1) The Committee for the Regulation of Petroleum Supplies on which the Admiralty, War Office, Board of Trade and Ministry of Munitions were represented and which reported to the Ministry of Munitions. This committee dealt with the maintenance and proper distribution of petroleum supplies other than those directly imported for Government use. (2) The Petrol Control

[1] Hist. Rec./R./1970/1. [2] Hist Rec./R./1970/10. [3] Hist. Rec./R/1970/1.

Committee, which reported to the President of the Board of Trade, and on which Government Departments which were users of petrol were not represented. (3) The Colonial Office Inter-Departmental Committee on Oil Leases in Crown Colonies. There was also a standing Admiralty Committee dealing exclusively with Admiralty requirements.[1]

The appointment of a body possessing co-ordinating and, where necessary, controlling functions in regard to petroleum matters was a pressing need, and in February, 1917, at the suggestion of the Ministry of Munitions, an Inter-Departmental Petroleum Committee, consisting of representatives of the Admiralty, the Board of Trade, the War Office, the Ministry of Munitions, the Colonial Office, and the Controller of Shipping, was appointed with the approval of the War Cabinet. The Chairman was Mr. Pretyman, Civil Lord of the Admiralty. Professor Cadman and Sir Boverton Redwood were added to the Committee as technical advisers and representatives of the Foreign Office and the India Office attended as occasion required. The terms of reference agreed upon were :—

> "To consider all questions of petroleum products and make such arrangements as will secure the best means of providing the necessary supplies and their allocation for military, naval and civil requirements, and to co-ordinate and determine the policy of departmental and other Committees dealing with various sections of the subject, subject to the usual procedure in regard to obtaining the sanction of the Treasury and Cabinet to important matters of expenditure or policy."[2]

Later, on the decision of the War Cabinet, the question of safeguarding supplies of essential petroleum products was placed in the hands of a responsible Minister, the Secretary of State for the Colonies (Mr. Walter Long, later Lord Long) being selected, and the Inter-Departmental Committee, which received new terms of reference,[3] was represented on this Petroleum Committee by its Chairman.

(*e*) THE POOL BOARD.

On 20 February, 1917, a meeting of importers and distributers was held, at which the suggestion of pooling supplies was brought forward.[4] This suggestion originated with the Director of Munitions Petroleum Supplies (Mr. Fry). It was approved by the Minister (Dr. Addison), and through the efforts of the Inter-Departmental Committee[5] a Pool Board was formed to regulate the supply, importation and distribution of petroleum products. It consisted of six importing and distributing companies, namely the Anglo-American Oil Company (controlled by the Standard), the Shell Marketing Company, the Anglo-Mexican Petroleum Company (including the Bowring Petroleum Company), the British Petroleum Company (including the Homelight Oil Company), the Union Petroleum Products

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[1] C.R.V./Gen./749. [2] *Ibid.* [3] See below, p. 146.
[4] C.R. 4523. [5] HIST. REC./R./1970/3.

Company, and Messrs. H. P. Wheatley and Company. It was agreed that the Government, through the Board of Trade,[1] should exercise general supervision over the policy and conduct of the Pool Board, leaving the details of organisation and management in the hands of the Pool Board as far as possible. The Government would in future purchase its supplies for immediate requirements in this country through the Pool Board instead of as formerly from individual companies. The products to be dealt with were kerosene, benzine, gas oil and fuel oil, and the quantities of these to be imported were to be determined by the Government in consultation with the Pool Board. The arrangements made by the Pool Board were to come into force on 2 April, 1917, and it was to continue during the period of the war and for one month after.

(*f*) The Petroleum Committee, the Petroleum Executive and the Inter-Allied Conference.

The existence of independent committees (e.g., the Petrol Committee and the Inter-Departmental Committee) led to confusion and overlapping, and Mr. Walter Long, at the request of the War Cabinet, investigated the whole question of the control of petrol and petroleum products and presented a report on 13 June, 1917. As a result it was decided that there must be a controlling authority, whose decision would be final, subject to reference to the War Cabinet if the fighting forces were affected, and that executive action must be left to Departments of State, each in its own sphere, subject to arrangements for co-operation and co-ordination, and subject to the decision of the controlling authority in case of dispute. In accordance with the decision the Secretary of State for the Colonies was appointed the controlling authority on all questions of petroleum products and their substitutes. He was to decide any dispute between Departments or the committees subordinate to them, referring to the War Cabinet only if the fighting forces were affected. The existing terms of reference of the Petrol Control Committee and the Inter-Departmental Petroleum Committee were cancelled, and it was arranged that the Board of Trade was to be the Department responsible for the allocation of supplies of petroleum products for industrial purposes and for civil needs, and was to exercise its authority as regards distribution of petroleum products other than petrol through the Pool Board, and as regards the distribution of petrol through the Petrol Committee, to which executive powers might be delegated by the Board if it saw fit. The Inter-Departmental Committee was to consist of representatives of the Departments then represented on that committee, with the addition of the Board of Agriculture, and was to be advisory to all Government Departments dealing with petroleum products, collecting and arranging information. It was to co-ordinate the work of Departments and arrange co-operation, but it was to have no executive functions save by delegation from the controlling authority. The Ministry of Munitions was to deal with home production.[2]

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[1] Hist. Rec./R./1970/1. [2] C.R.V./Gen./749.

The Secretary of State for the Colonies, as controlling authority, was to preside over periodical meetings of a new Petroleum Committee, which was to consist of the Chairman of the Inter-Departmental Petroleum Committee, the Petrol Committee (later the Petrol Controller), the Pool Board and Professor Cadman, who acted as Mr. Long's technical adviser and as liaison officer between the Departments and committees concerned.[1] Representatives of the Admiralty, the Colonial Office, etc., also sat upon this committee which was competent to deal with questions of general policy, to settle any questions in dispute between Departments and committees and to arrange for any executive action which ought to be taken by the Departments concerned. The committee held its first meeting on 3 July, 1917.[2]

Subsequently, in December, 1917, an executive department, known as H.M. Petroleum Executive, was formed to deal with all matters of policy in connection with the petroleum products in which the Government was interested, and to co-ordinate as far as possible the work of the different Government Departments in so far as they were concerned with questions connected with petroleum. Professor Cadman became Director of this Petroleum Executive, and from that time onwards important questions relating to petroleum, which previously had been submitted to the Inter-Departmental Committee, were submitted by Government Departments in the first instance to the Petroleum Executive for submission to Mr. Walter Long.[3]

Later, in February, 1918, an Inter-Allied Petroleum Conference was set up to interchange information and consider and deal with the petroleum problems of the Allies in connection with the war. Professor Cadman acted as Chairman of this organization.[4] It was agreed that this conference should sit alternately in London and Paris.

(*g*) THE MINERAL OIL PRODUCTION DEPARTMENT.

In the summer of 1917 the position was an anxious one, and on 27 June, 1917,[5] a conference on fuel oil production was held under the chairmanship of Sir L. Worthington-Evans, at which representatives of the Admiralty, the Petroleum Research Board, the Coal Controller, the Ministry of Munitions, the War Office and the Board of Trade were present. The Admiralty stated that existing stocks were causing grave anxiety and that in view of the rapidly increasing number of oil-burning vessels no effort should be spared which might ameliorate the situation. The possibilities of developing home sources of supply were accordingly discussed, *viz.*, stimulating the existing Scotch shale industry, utilising deposits of shale found in England, distilling cannel coal, which had hitherto been mined in connection with the production of gas, and boring for natural petroleum. The low temperature distillation of coal other than cannel was also considered, and Sir George Beilby, Director of Fuel Research, gave information on the coke oven position. He stated that coke ovens could not be regarded as a very promising source of supply, since the amount of fuel oil produced by high

[1] See below, p. 149. [2] HIST. REC./R./1970/15. [3] C.R.V./Gen./1678.
[4] HIST. REC./R./1970/15. [5] HIST. REC./R./1970/2.

temperature distillation in coke ovens was not large in proportion to the material handled. There was already a powerful stimulus to coke production on behalf of the metallurgical industry, but further advance beyond that already planned could not be looked for. As regards the emergency development of low temperature distillation, he foresaw great difficulties owing to the economic difficulty of disposing of the resultant coke, which was soft and friable and therefore unsuited for metallurgical purposes.

With regard to the development of all the suggested sources of supply it was obvious that further research was advisable before entering on any large scale undertaking. The need for home production of fuel oil was, however, represented by the Admiralty to be so urgent that it was agreed that a plunge must be taken even though research could not guarantee results, and it was desired that the Ministry of Munitions should make itself responsible for the production (though not the distribution) of oils from these various sources, it being understood that the Minister should receive every assistance from the experts who had been working on the problem.

This was expressed by the chairman who, at the close of the conference, said :—

> " As I understand, it is desired that the Ministry of Munitions should make itself responsible for the production of oils from these various sources—not for distribution, I gather. The Minister is willing to add that to his other labours only on the complete understanding with everyone present that he is going to receive every sort of assistance from all the experts who have been working at this—from the Coal Controller and everybody concerned—because it is no light task to endeavour to bring research up to the practical part and take the plunge at the right moment, when research will, naturally, not guarantee the results. That is what it means, I think—we have to go ahead of research. . . . Research is not going to give any guarantee as to results. We have not got to rest upon experts, but upon ourselves. We can only do that if we have the support of everybody. But the Admiralty makes out a case which is unanswerable, and somebody has to do it. The Minister is willing to do it if he can rely upon everybody's support and it is realised that we are turning over a completely new page."[1]

In July, 1917, it was decided that the existing Petroleum Supply Branch of the Ministry should be reconstituted and should from that time be known as the Munitions Mineral Oil Production Division (M.M.O.P.).[2] This department which was to deal with the home production and distribution of petroleum and other mineral oils, was attached for general office administration to the Director-General of Munitions Supply and was under the immediate control of Professor John Cadman as Controller of Mineral Oil Production. The Controller reported to the Minister through Sir L. Worthington-Evans, who was assisted by an Advisory Board, of which Sir Frederick Black was

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[1] Hist. Rec./R./1970/2. [2] General Memorandum, No. 15.

Chairman.[1] This Advisory Board was constituted with a view to bringing into close contact those departments which were directly interested in the work of production and from whom it was important that technical assistance should be obtained. Its recommendations were submitted to the Inter-Departmental Committee. The Controller was assisted by the officers in charge of branches dealing with (1) the production of mineral oil from shales, (2) the production of mineral oil from coal and cannel, (3) the treatment and refining of mineral oil, (4) supplies of fuel oil, lubricating oil, and petrol for munition firms, and the distribution and storage of home-produced mineral oils. Other questions relating to mineral oils were, of course, dealt with by the department, and the Turpentine, etc., Control Order, 25 January, 1918, was administered by it.

At the same time it was decided that the Petroleum Research Branch under Sir Boverton Redwood, which was at this time administered and paid by the Admiralty,[2] should be transferred from the Ministry to work under the Chairman of the Inter-Departmental Committee on Petroleum Products. Sir Boverton Redwood shortly afterwards became Director of Technical Investigation in the newly formed Petroleum Executive, and Mr. Winmill was appointed Director of Petroleum Research in his place. Later, Mr. Winmill became Director of the Technical Section of the Munitions Mineral Oil Production Division. At the end of September, 1917, a change was made in the organisation of the Division as the Minister then decided that it should in future form part of the Department of Explosives Supply. Colonel Sir Arthur Churchman then became Director, with Professor Cadman as his chief technical adviser.[3] Professor Cadman at the same time became chief adviser on all oil questions to Mr. Walter Long, and henceforward acted as liaison officer between different Departments, being later appointed Director of the Petroleum Executive.

IV. Development of the Production of Fuel Oil from Home Sources.

The main object of the Mineral Oil Production Department was to carry out any practicable scheme which might be devised to develop fuel oil supplies from home sources, and the two main points to which it directed its attention were the distillation of cannel coals and the development of the Scotch shale industry.[4]

(*a*) Production of Mineral Oil from Cannel Coal.

A report issued by the Petroleum Research Department under Sir Boverton Redwood, in October, 1917, recommended that endeavours should be made to produce oil from native bituminous minerals, and advised the erection of large numbers of low temperature retorts, mainly of the Del Monte type, for non-caking cannels.[5] The recommendations of the Research Department were not considered practicable by the Production Department of the Ministry of Munitions,

[1] Hist. Rec./R./1970/15.
[2] M.C. 1041.
[3] General Memorandum, No. 27 (27/9/17).
[4] Hist. Rec./R./1970/10.
[5] *Ibid.*

owing to shortage of labour, lack of material, over-estimation of the quantities of retortable mineral available, and especially the length of time which would elapse before the retorts could be completed with the necessary subsidiary plant and machinery, railway sidings and other necessary organisation and facilities. In view of the importance of the matter and the difference of opinion, a special committee was appointed in March, 1918, with Lord Crewe as Chairman, to consider the position. This committee, after the fullest investigation, issued a report in July, 1918, on the production of fuel oil from home sources, which amply confirmed the action of the Mineral Oil Production Department of the Ministry of Munitions.[1] Meanwhile, the Petroleum Research Department had been re-organized and amalgamated with the Production Department in order to ensure more effective co-ordination of investigation with production. A scheme had been put forward by the Production Department, under Sir A. C. Churchman, by which native minerals could be carbonised for the production of oil in existing apparatus and by already organised staffs in gas works. One battery of Chiswick retorts (i.e., the Del Monte type recommended in the report of the Petroleum Research Department) was set up at Nottingham, in order to compare on an industrial scale this system of carbonisation with that in the vertical gasworks retorts. The results of experiments carried out in continuous vertical retorts at gasworks, showed that not only could existing plant be modified at comparatively small cost to produce yields of oil as large and of as good quality as could be obtained by any other method, but at the same time, by adopting a method of low temperature distillation for oil at the top of the retort, followed by a high temperature distillation in the lower part, the normal output of gas from the works could be maintained.[2] This policy was adopted with the result that sufficient plant was made available at gas works[3] to deal with the whole of the material suitable for oil production which could, under war conditions, be produced in England and Scotland. The oil produced by this method was almost completely miscible with petroleum without refining.[4]

(*b*) Use of Tar Oils as Substitutes for Petroleum.

Besides initiating this new source of supply of oil,[5] the Mineral Oil Production Department developed through the supplies branch (under Mr. Fry) the use of creosote produced from coal tar as a substitute for imported petroleum. With a view mainly to saving tonnage, it was decided in June, 1917, to stop the export of tar oils, except under permit, and in order to provide an outlet for the oil, the Admiralty and the Ministry of Munitions agreed to take such quantities as had previously been exported, at the rather low price of 67/6 per ton.

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[1] Cd. 9128 of 1918.

[2] It was found that cannel coals yielded larger quantities of oil and tar than did bituminous coals.

[3] For type of agreement, see that made with the Corporation of Nottingham. (Hist. Rec./R./1970/10).

[4] Hist. Rec./R./1970/10. [5] *Ibid.*

The producers, however, were able to secure better prices from other consumers than the price agreed upon with the Government, and in consequence the Admiralty only obtained tar oil at the rate of about 80,000 tons per annum instead of an estimated 150,000 tons, while the consumption of straight creosote as fuel in inland furnaces and engines considerably increased. In order to obtain larger supplies for the Admiralty, an Order prohibiting the use of creosote, except under license was issued on 13 July, 1917. This Order, subjecting all dealings in creosote and other oils to license, prohibited their use for treating wood or road-making, except under permit from the Ministry, and required from all consumers returns as to the sources from which their oils were obtained, and details concerning their use.

Shortly afterwards (4 September, 1917) a Coal Tar Order was issued, with a view to securing the distillation of the maximum quantity of tar, and the recovery of the creosote fraction, which was urgently needed by the Admiralty for fuel oil.[1] This order was superseded by the Tar (Coal and Water-Gas) Order, of 31 December, 1917, which included the tar obtained by carburetting water-gas, since from this tar a large proportion of oil suitable for fuel could be obtained by distillation.

A requisitioning order, the Tar Oils Order, was issued on 23 October, 1917, under which possession was taken of those fractions suitable for use as fuel, dealings in them being prohibited except under license, while maximum prices for the oils were fixed. The term "tar oil" in this order included creosote oil, green oil, sharp oil, anthracene oil, and other oils produced by the distillation of coal tar, coke-oven tar, producer tar, water gas-tar, and Mond gas-tar.

This Tar Oils Order, 1917, was superseded, however, by a further order, issued on 1 February, 1918, under which the meaning of the term "Tar Oil" was extended to cover further products of distillation.

The following estimated figures for the production and distribution of creosote during 1913 and at the time of the prohibition Orders issued in July, 1917, may be usefully compared with the actual figures for consumption during the year 1918.[2]

	1913. Tons per annum.	July, 1917. (At the rate of) Tons per annum.	1918. Tons per annum.
Production	330,000	360,000	396,000*
Consumption—			
Exports	172,000	40,000 (to France)	9,117
Civil purposes	158,000	240,000	216,565
Admiralty	—	80,000	199,340

* The consumption during 1918 necessitated the withdrawal of 29,000 tons from stocks held by the makers.

[1] Vol. VII, Part IV, Chap. II.

[2] HIST. REC./R./1970/10.

The results of the Orders concerning tar oils are shown by the fact that the Admiralty creosote supplies which in 1916 were 3,342 tons and in 1917 were 102,578 tons, increased in 1918 to 199,340 tons. In addition, a further 50,000 tons of petroleum oil was set free for Admiralty use, being replaced by tar oils in the internal combustion engines.

The use of pitch as a fuel in furnaces and under boilers was encouraged, experiments showing that mixtures of pitch and creosote, containing as much as 75 per cent of pitch, might advantageously be used.[1] Pitch was first used as fuel in November, 1917. In that month 860 tons were used, while the following month the amount had increased to 3,400 tons.

Thus the result of these measures was that the supply of fuel oil for other than naval and military purposes was assured from home sources alone. In addition large quantities of creosote were supplied to the Admiralty for use as fuel oil, home produced creosote being substituted for imported petroleum in Diesel and semi-Diesel engines, and a mixture of creosote and pitch being substituted for petroleum in oil fired furnaces and boilers. By these methods, the petroleum released for, and the creosote directly supplied to, the Admiralty together increased sevenfold the pre-war supplies of oil from home sources, which consisted merely of the oil from the Scottish shale oil industry.

No direct production of petrol or motor spirit was undertaken by the Mineral Oil Production Department, but the saving of tonnage by the substitution of home supplies for a proportion of the imported oils allowed a greater margin for the importation of the necessary petrol, and the action of the other branches of the Ministry of Munitions,[2] e.g., the Explosives Department, in securing the maximum recovery of light oils from coke ovens and gas works by developing the output from high temperature distillating plants, increased very largely the supply of home-produced substances which could be used as motor spirit. Moreover, a Benzol and Naphtha Order, issued under the Defence of the Realm Regulations on 29 August, 1917, prohibited all dealings in crude benzol, crude naphtha and light oils containing recoverable quantities of benzol and toluol except by licenses issued by the Director of the Raw Materials section of the Explosives Supply Department. This Order, which was issued with a view to conserving supplies of benzol and toluol for explosives manufacture was followed later by the Solvent Naphtha Order on 31 December, 1917.[3]

(*c*) Development of the Shale Oil Industry.

At the outbreak of the war, a long-established shale oil industry existed in Scotland. Previous to the conference on fuel oil production, held on 27 June, 1917, a committee had been appointed, working under Professor Cadman, to take steps to secure an increase in the output of oil from the Scottish shalefields.[4] The steps taken to secure a larger production were as follows :—(1) The suspension of the Eight Hours'

[1] C.R. 4639. [2] X./235/44. [3] Vol. VII, Part IV, Chap. II.
[4] Hist. Rec./R./1970/5.

Act as applied to shale mines, a special Bill being introduced for the purpose; (2) the recall of workmen from the colours; (3) the transfer of workmen from mines where they could best be spared to others where acute shortage of labour existed; (4) the rearrangement where necessary of labour underground; and (5) the formation of joint committees of mine managers and workmen's representatives to deal with cases of absenteeism.

By the middle of the year 1917, the Scotch shale industry had almost reached its limit of production with the then existing arrangements. Crude oil was being produced at the rate of about 189,000 gals. per day. The maximum amount of oil suitable for naval purposes was not, however, being obtained from the crude oil, since the production of other products—notably, paraffin wax—entailing elaborate processes in refining, was more profitable.[1] By adopting what was known as Scheme G, which dispensed with part of the refining process, it was estimated that the amount of fuel oil produced could be greatly increased at the expense of other products, while an additional output of some 20 per cent. of marketable product could be secured. Such an alteration in refining methods involved, however, the loss of the existing market for refined products, and the companies were naturally unwilling to embark voluntarily on such radical changes in the refining methods unless they could be assured against loss.[2] In furtherance of the policy of increasing home production adopted by the inter-Departmental conference on 27 June, in order to relieve the shortage experienced by the Admiralty, it was decided by the Munitions Mineral Oil Production Department in August that Scheme G should be adopted, and this decision was later endorsed by Mr. Walter Long. To ensure an outlet for the increased output of fuel oil the companies demanded a contract with the Admiralty over a long period of years, before embarking on Scheme G, but the Admiralty demurred in view of existing inflated prices. The Admiralty therefore suggested, on 22 December, 1917, that the carrying into effect of Scheme G should be undertaken by the Ministry of Munitions, but the Ministry could only accomplish this by taking over the Scottish shale oil companies under the Defence of the Realm Regulations, which for several reasons appeared inadvisable. At the instigation of the Ministry of Munitions an inter-departmental meeting was accordingly held to consider the adoption of Scheme G by the Scottish shale oil companies (5 April, 1918). At this meeting it was stated that the total consumption of fuel oil by the navy was 3,500,000 tons a year. Creosote was being supplied to the Admiralty at the rate of 250,000 tons a year, and by the use of a mixture of creosote and pitch it was hoped to effect a saving of 100,000 tons a year. Oil was also to be produced by carbonising cannel coal, and it was estimated that the total supply of oil to be obtained from coal might be taken as 500,000 tons per annum. The annual output of fuel oil from the Scottish shale works was then 55,000 tons, of which the Admiralty obtained 35,000 tons. If Scheme G were adopted it would add a net 40,000 tons a year. This was a relatively small quantity, and though the Admiralty emphasised the fact that the urgency of oil supplies for the navy was as

[1] M.C. 1001. [2] M.C. 146.

great as ever, they were of opinion that the net increase of 40,000 tons per annum which would be realised by the adoption of Scheme G would not justify the conclusion of a long term contract at the existing inflated prices and the attendant dislocation of the shale industry with its further detrimental effect on the jute industry through the loss of home-produced batching oil. The Minister of Munitions agreed (24 April) that the increased production secured by the application of the Scheme G system of refining Scotch shale oil would not be commensurate with the cost and other disadvantages involved.

The development of the Scottish shale industry to its maximum production was, however, considered of such importance, that in May, 1918, Mr. Long stated that no reduction in output should be allowed by the removal of men from the industry.[1]

The utilisation of English deposits of shale was also considered, but since the seams of shale were found to be thin and separated by layers of clay, and since it was increasingly difficult to obtain fresh labour and plant, it was not found advisable to work it ; a further reason against doing so being the presence of sulphur in the oil retorted from the shale.[2]

(*d*) BORING FOR OIL.

The possibility of natural petroleum occurring in Great Britain in appreciable quantities was not to be disregarded, and at a meeting on the home production of mineral oils held at the Ministry of Munitions on 1 February, 1917, at which Sir Frederick Black, Sir Boverton Redwood, Mr. Y. C. Clarke and Mr. Houghton Fry were present, it was stated that Lord Cowdray and Lord Murray had made all arrangements for carrying out drilling operations on a comprehensive scale in various parts of Great Britain, employing their own capital for the purpose.[3] Immediate drilling was not, however, deemed advisable by Lord Cowdray when he was approached by the Admiralty on the subject in June, as his firm did not control anything approaching the areas requisite to obviate the evils of the small block system. He accordingly recommended that a system of national drilling licenses should be adopted.[4]

At a meeting of the Inter-Departmental Committee on Petroleum Products held at the Admiralty on 31 July, 1917, the introduction of a non-contentious Bill nationalising petroleum was discussed, the suggestion being that the Government should take the risk of drilling and employ Lord Cowdray as contractor on a time and percentage basis.[5]

A Petroleum (Production) Bill which made provision for searching and boring for petroleum was therefore introduced in August, 1917. This Bill, which gave His Majesty exclusive right to get petroleum within the United Kingdom, was designed to prevent various abuses that had attended the development of oil fields in other countries.[6]

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[1] M.C. 146.
[2] HIST. REC./R./1970/1.
[3] C.R. 4526.
[4] HIST. REC./R./1970/15.
[5] HIST. REC./R./1970/10.
[6] HIST. REC./R./1970/11.

As regards the important question of property in the oil, the policy adopted in this Bill was that the owner of the surface was to be allowed a limited right of property measured by a fixed royalty. Largely owing to the royalty provisions the Bill failed to pass the House of Commons.[1]

Though the Bill had been lost the matter was not allowed to drop, and an Order in Council and a new Defence of the Realm Regulation[2] followed in January, 1918, under which the Board of Trade and the Ministry of Munitions received powers to search for petroleum, to enter upon and take possession of any land, and to sink wells and construct works on it; at the same time searching for or getting petroleum without authority was prohibited.

Lord Cowdray's firm, Messrs. Pearson and Son, who had wide experience of American oilfields and who had devoted considerable labour and expense since the beginning of the war to preliminary research on the petroliferous deposits of the United Kingdom and to negotiations for leases and lands in connection therewith, offered to place the services of the firm and its geological staff at the disposal of the Government, free of all cost, for the purposes of exploration and development for the period of the war, provided that the Government would agree to take steps to protect the oilfields from indiscriminate drilling not only during the continuance of the Defence of the Realm Regulations, but after the war.[3] This assurance was given by the Government and the offer accepted in March, 1918. Messrs. Pearson & Son were accordingly appointed Development Managers to act as the agents of the Government, who were to provide the necessary money and other facilities for the work. The agreement[4] was dated 10 September, 1918. By it the Minister undertook to take possession of any land reasonably required for the operation of sinking wells or constructing works under the Defence of the Realm Regulations or otherwise.

A second Petroleum Bill, which did not touch the royalty question, was brought before Parliament just before the end of the Session in August, 1918.[5] Its main object was to extend the prohibition against boring and searching for petroleum without a licence. This Bill was passed by the House of Commons, but consideration of it in the House of Lords was deferred until the following Session, and the policy to be adopted by the Government on the subject of ownership of petroleum produced in the United Kingdom was left for post-war decision.

V. Substitutes for Oil used for Motor and Traction Purposes.

(*a*) Gas Traction.

The increasing stringency of petrol regulations in 1917 resulted in other generators of motive power being resorted to, and the running of motor-car engines on coal gas instead of petrol was taken up.[6] In

[1] Hist. Rec./R./1970/14.
[2] Regulation 2AAA, 16 January, 1918 (see Appendix IV).
[3] Hist. Rec./R./1970/10.
[4] Hist. Rec./R./1970/9.
[5] Hist. Rec./R./1970/11.
[6] *Ibid.*

October, 1917, a number of vehicles were exhibited in London in which the gas was stored in collapsible bags carried on the roof. The Ministry of Munitions at first gave a ruling that gas used in this way was not a "petrol substitute," and large numbers of commercial vehicles and others were equipped to use gas. Just before Christmas, 1917, however, it was decided by the Board of Trade, in concurrence with the Petroleum Executive, that the use of gas for motor cars must be brought under the same regulations and restrictions as the use of petrol, since it was desired that it should be used as a substitute for, rather than in addition to petrol, and in the Motor Spirit (Consolidation) and Gas Restriction Order, 1918, which came into operation on 10 January, the two fuels were equally restricted as regards purposes of use, though the quantity of gas used was not limited where licences to use it were granted. At the instance of the Explosives Supply Department, however, the Petroleum Executive arranged with the Board of Trade that certain specific gasworks should be prohibited from providing gas for motive purposes.

Meanwhile a Gas Traction Committee had been appointed by Mr. Walter Long as head of the Petroleum Executive. This Committee, of which Sir Boverton Redwood was chairman, held its first meeting on 6 December, 1917. The subjects of its investigations were the best methods of utilising gas for driving motor vehicles and safeguards against any danger attending its use. In April, 1918, it reported that gas could be safely and effectively substituted for petrol in the usual motor-car engine, and it recommended the formation of an expert sub-committee (which was subsequently formed) to investigate a number of technical problems, the solution of which would tend to promote the efficient use of gas for traction.

(*b*) Power Alcohol.

Another proposed substitute for petrol for power and traction purposes was alcohol, but this was not dealt with officially until the autumn of 1918.[1] On 10 October, 1918, an Inter-Departmental Committee on Alcohol-Fuel, under the chairmanship of Sir Boverton Redwood, was appointed by Mr. Walter Long, to consider and report on the production and utilisation of alcohol for power and traction purposes. On 23 June, 1919, the Committee reported that there were sufficient grounds to justify State action in fostering the production and utilisation of alcohol for power purposes, and recommended that an organisation should be established by the Government to initiate and supervise experimental and practical development work at home and overseas, on the production and utilisation of power alcohol, and to report from time to time for public information on all scientific, technical, and economic problems connected therewith.

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[1] Hist. Rec./R./1970/13.

CHAPTER XI.

MISCELLANEOUS MATERIALS.

I. Abrasives.

Only a semi-official control was established of the abrasives used for the manufacture of grinding wheels for the Machine Tool Department. The function of the Materials Department was confined to securing the semi-manufactured material for the wheel makers; responsibility for an adequate supply of wheels rested with the Machine Tool Department, practically the whole of its purchases being made from American and English companies.

The abrasives in use included the natural abrasives (emery, garnate, and corundum), those manufactured from coke and silicon (carborundum and carbolon), and those manufactured from bauxite (glechite, aloxite, and alundum). Before the war 90 per cent. of the high-grade abrasive grinding wheels used in this country were imported from America, where they were manufactured either from bauxite, or coke and silicon, the trade names of the manufactured article being aloxite, alundum, and carborundum.

Aloxite and alundum were chiefly manufactured by the Carborundum Company at their works at Niagara Falls, the raw materials containing approximately 60 per cent. of alumina. The bauxite was first fused in an electric furnace and then ground into sizes suitable for the manufacture of grinding wheels. To a less extent carborundum was also manufactured in America, where the vitrified wheel industry depended entirely upon these semi-manufactured materials.

In the early part of 1917, owing to the growing submarine menace, supplies of wheels from America were not assured. Cheap electric power for fusing bauxite was not available in Great Britain; and even if it had been, there was, during the war period, no bauxite to spare for this purpose. Of the natural abrasives, however, corundum had before the war been imported into the United Kingdom from Madagascar for the manufacture of vitrified wheels, at the rate of about 40 tons per month, and it became necessary to increase the imports of corundum to the United Kingdom to take the place of the aloxite and other abrasive material formerly imported by wheel makers from America. There were only a few firms, notably the Carborundum Company, Manchester; the British Abrasives Wheel Company, Sheffield; and the Universal Company, Sheffield, making these vitrified wheels, and their production was almost negligible in comparison with war requirements.

Arrangements were therefore made, by developing corundum deposits in the Transvaal, to increase the imports of this stone to 400 tons per month. The stone was ground and prepared for making into

wheels by the Carborundum Company, Manchester. The corundum was imported by Corundum, Ltd., at a price agreed upon with the Materials Department, and prices for the manufacture of the ground stone into wheels were also settled by agreement between the wheel makers and the Ministry.

While wheels made of corundum were better for some purposes than those made from bauxite, and in general there was little to choose between them, vitrified wheels of carborundum were the best for precision grinding. Various experiments were, therefore, made during the latter part of the war in the manufacture of carborundum in this country, which were in an advanced stage at the time of the Armistice; but on the conclusion of hostilities the scheme for manufacture in the United Kingdom was dropped, as it could not compete with the carborundum produced by cheap water-power in America.

When hostilities ceased the stocks of uncrushed corundum in this country aggregated 1,034 tons, in addition to approximately a three months' supply of crushed material held by Messrs. Corundum, Ltd., and the wheel makers. In view of the large stocks held and contracted for by the company, they had to ask for financial assistance early in 1919, as wheel makers, owing to the cessation of work on munitions orders, were not buying one-tenth of their former quantity of crushed corundum. It was recognised that Corundum Ltd. had rendered a valuable service to the country, and a loan of £12,000, repayable in twelve months, was made to them jointly by the Ministry and the Bank of Scotland.

Garnate was mainly used for shoe work and the polishing of leather, but the discovery of an artificial abrasive made from furnace slag, enabled imports to be reduced almost to vanishing point.

The average annual consumption of emery stone, which is an impure form of carborundum, in the United Kingdom is from 8,000 to 10,000 tons. Adequate supplies were formerly available from Turkey in Europe and from Asia Minor; but during the war, the only practicable source of supply was from Naxos, an island in the Greek Archipelago, the mines on which, owned by the Greek Government, had an average annual output of 7,000 tons, of which large quantities were being sold to the United States and Sweden.

Early in 1916, in view of the shortage in this country, the Foreign Office attempted to induce the Greek Government to reduce the quantity supplied to Sweden and to maintain regular supplies to the United Kingdom, but failed to obtain any response to their request.[1] Meanwhile, the French Government entered into an agreement with the Greek Government to purchase the output and stock in Greece of this material and undertook to discharge the whole liability for each purchase direct to the Greek Government, thus entirely controlling the exports.

The British Government then endeavoured to arrange with the French Government, through Major Hausser of the Commission Internationale de Ravitaillement, to share equally in the stocks and

[1] (Printed) *Weekly Report*, No. 32, I. (4/3/16); No. 33, I. (11/3/16).

output from Naxos, but were informed that they could only be allowed 1,750 tons of first quality from stock and 2,200 tons of first quality from the 1916 output, as well as the second quality (6,000 tons), but that as soon as Russian requirements were met, the French Government would give England the remainder of the 1916 output.[1]

In a communication of 4 July, 1916, to the Ministry of Munitions, Major Hausser defined the terms upon which the French Government were prepared to supply this material; all classes of emery were to be sent to Marseilles, and no direct shipments whatever made from Syra to any British port.[2] The French Government was to be paid the cost price for ore delivered in Marseilles at the rates of 150, 125 and 100 drachmae per ton for the three qualities respectively, plus 25/- per ton transport from Syra to Marseilles, and also storage and other incidental expenses, amounting to 2/3 per ton; any other costs and arrangements for transport to new destinations were to be borne by the transferee. In October, 1916, it was estimated that the total shipments from Naxos, between then and the end of the year, would amount to 14,000 tons (7,000 of first quality), which would enable a reserve to be accumulated.[3]

There were at this time eleven firms dealing in emery stone in Great Britain, and one syndicate (Levant Mineral Company, who were the largest purchasers). The latter was commissioned by the Government to distribute the stone shipped to London among the interested firms. It was found that the net cost of the mineral after payment of all charges for storage and freight (the British Government undertaking insurance risk from Marseilles) enabled it to be sold at about £9 per ton for the best quality. Supplies continued to arrive henceforth satisfactorily down to the cessation of hostilities.

In February, 1919, the Greek Government requested to be released from the contracts regarding Naxos emery, and the French and British Governments agreeing, the contract was terminated in March, 1919.

II. Electrodes.

Little difficulty arose in connection with the supply of electrodes until 1917. The principal industries in which electrical furnaces were used for munitions purposes were the steel trade, using both graphite and carbon (or amorphous) electrodes, the manufacture of aluminium and alloys, carbide and phosphorus which required the amorphous type, and chlorine, optical glass and silica ware, electric welding, abrasives and cupro-nickel which used graphite electrodes.[4]

Graphite electrodes were made in America, where two firms, the Acheson Graphite Company and the National Carbon Company, manufactured and exported all those used by British firms.[5] Carbon electrodes were also imported from America but on a far smaller scale,

[1] C.R.V./Gen./040; Minutes of conference at Paris, 6 and 7/4/16. (HIST. REC./R./1800/6).
[2] A.M.2/513. [3] *Ibid.* [4] M.C. 466. [5] C.R.V./Gen./0418.

as the greater part of British requirements were met by home manufacture,[1] while as there was no plant in England capable of producing the largest sizes, a certain quantity of these were imported from Sweden. In the spring of 1917, the construction of two factories was begun to secure British manufacture of the largest electrodes required,[2] and the output was developed until, in the summer of 1918, British firms were independent of Swedish supplies.[3]

Early in 1917 supplies were hardly satisfactory and returns were required from all importers, manufacturers and consumers and from electric-furnace makers, who periodically supplied information as to the installations on hand, with the probable dates at which they would come into operation.[4] Owing to the submarine campaign difficulty was experienced in securing petroleum-coke from America for the manufacture of electrodes, and as the failure of an adequate supply of these would seriously affect, among other industries, the whole English and Norwegian production of aluminium, arrangements were made to produce pitch coke in a national factory, thus rendering the import of petroleum coke unnecessary.[5] The home production of electrodes in March, 1917, was 340 tons monthly, while 34 tons of graphite and 63 tons of carbon electrodes were imported. Against this total of 437 tons the consumption was 385 tons, while large stocks were held[6] and requirements were adequately met throughout the summer.[7]

In September, 1917, the Ministry took possession of all electrodes of more than 4 ins. diameter in the hands of importers, and from this time all imports were allocated for war purposes by direction of the Ministry. In view of this control, when, in November, electrodes were placed on the American conservation list (which meant that they could not be exported without a certificate that they were required for munitions work) the Ministry proffered a general guarantee to cover all imports in order to avoid the delays involved in the exchange of formalities over each separate consignment.[8]

In view of the importance of maintaining adequate supplies, the Co-ordinating Committee decided in January, 1918, that a special committee should be appointed to consider or revise existing arrangements for the requisition, supply and allocation of electrodes. This committee found that the position of amorphous (carbon) electrodes was satisfactory, but as the supply of the graphite type was entirely dependent on American supplies, which might at any time be interrupted, the stocks of these should be increased. As graphite and carbon electrodes were to a large extent interchangeable, the position was less serious than it might have been, but in February a scheme

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[1] M.C. 466.
[2] C.R.V./S./0172.
[3] C.R.V./S./0528.
[4] M.C. 466.
[5] (Printed) *Weekly Report*, No. 84, III (17/3/17); No. 90, III (5/5/17).
[6] *Ibid.* No. 138, III (20/4/18).
[7] *Ibid.* No. 151, III (20/7/18).
[8] C.R.V./Gen./0418.

was initiated for the British manufacture of graphite electrodes by a group of firms including Messrs. Armstrongs, the Newcastle Alloys Company, and Priestman's Collieries. The position at the end of 1917 is indicated in the following table :—

Requirements (tons per month).	*Graphite.*	*Carbon.*	*Supplies (tons per month).*	*Graphite.*	*Carbon.*
Steel Works	80	225	From Sheffield works	—	130
Alloys	—	50	From Newcastle Alloys	—	70
Carbide	—	20	Imports from U.S.A.	200	80
Phosphorus	—	20	Imports from France	—	30
Others	50	—	Imports from Sweden	—	20
	130	315		200	330

The stocks in hand were equal to about 2½ months' supply, and it was estimated that by June, 1918, the total requirements would be raised to 180 and 590 tons respectively and the supply to 285 and 725 tons. At the end of 1918, assuming that no further furnaces were installed and that imports of graphite could be maintained, the consumption of electrodes would be well covered by the available supplies. In addition to the two British firms shown in the table as producing carbon electrodes, the Alby Carbide Company completed plant in 1918 with a nominal capacity of 5,000 tons per annum, which under their agreement with the Ministry they might at any time be called upon to duplicate,[1] and in August, 1918, Treasury sanction was obtained for the purchase in America of 2,220 tons of graphite electrodes to cover the requirements of the current year.[2]

III. Mica.

(*a*) Fixing of Prices.

Mica, which is used in the manufacture of magnetos and in wireless and electrical work, is one of the most common and widely distributed minerals, and is found in almost every part of the world. The peculiar conditions which influence its mining, the impossibility of correctly or even approximately gauging the persistency of mica leads, or the quality of mica they carry, and the great loss in the product in its preparation for the market make the industry unattractive financially. Mining is therefore usually done in a very primitive manner with a minimum of plant and initial outlay, or the mica is extracted by open quarrying.

No actual records of world production before the war are available but it was approximately 100,000 hundredweight cases in 1913, of which about 75 per cent. was mined in India.

The following figures show the imports to London before the war ; fully 50 per cent. being re-exported to Germany :—

	1910.	1911.	1912.	1913.	1914.
Cases containing 1 cwt.	18,995 ..	23,236 ..	31,315 ..	40,174 ..	22,178

[1] M.C. 466.
[2] (Printed) *Weekly Report*, No. 155, IVA (17/8/18).

Before war broke out, Germany took approximately 80 per cent. of the Indian production (partly by direct importation and partly through London) and, in addition, took her own production from German East Africa, which was rapidly increasing, and a transfer of the world's market from London to Hamburg was being projected, owing to the great success and importance of the German electrical industry.

Up to October, 1915, the War Trade Department had been responsible for supplies of mica, but in order to assist that Department on the question of export licences, mica was transferred to the Raw Materials Department of the Ministry of Munitions in October, 1915.

The Department, after enquiry, came to the conclusion that there was no real shortage of mica, but there was a progressively increasing demand for certain sizes of "Ruby" quality, while mineowners were holding up supplies with a view to enhancing prices. Producers were finding it difficult to dispose of sizes and qualities which were unsuitable for munition purposes, the demand for these inferior grades being small.

As there was no regular market price, an agreed price list for a "fair average standard" of the most generally used qualities was drawn up after consultation with the chief firms in the Indian mica trade (November 25, 1915), the prices ranging from 16*s*. to 20*s*. per pound for highest quality clear ruby down to 2*d*. or 3*d*. a pound for stained and black spotted mica.

(*b*) The Appointment of Government Agents in India.

At a conference in the following week it was decided that in order to increase the supply of "best selected" mica, it was necessary to encourage the output of all grades of mica, which could only be accomplished by removing all restrictions on the sale of mica other than preventing it getting into enemy hands. Further, in order to ensure that all available supplies of "best selected" mica reached the firms in the United Kingdom which were making electrical condensers, it was proposed that Messrs. Chrestien and Company should be appointed as agents in India to inform the mica miners of the needs of the Government and to buy all the best quality mica and forward it to London, where it would be sold through brokers to the trade, the cost of the mica, plus profit, freight and brokerage, being fixed as a minimum selling price to the trade.

This proposal was submitted by the India Office to the Indian Government (11 December, 22 December, 1915),[1] which was also asked to put pressure upon disputants who were contesting the ownership of the Gawan mica mines in Bengal to compose their differences and reopen the mines. Subsequently (6 January, 1916), the Indian Government was informed that the Ministry of Munitions would like the Government of India to arrange terms of employment as agents direct with Messrs. Chrestien, and that payments made by the Government of India should be charged against Imperial funds.

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[1] D.D.G.(A.) 10472.

The Viceroy pointed out the difficulty of stimulating the production of mica unless the widest possible market for the lower grades was opened, and doubted the wisdom of insisting that all trade with the United States should be done through the United Kingdom (17 January, 1916). Some objection to the proposed appointment of Messrs. Chrestien as Government agents was also taken. The Madras Government thought that it was likely to cause friction with the trade, which would suspect the agents of trying to use their appointment to better their position in the mica industry at the expense of other firms. The Government of India therefore suggested (1 March, 1916) that Madras, where supplies of special quality mica were said to be unimportant, should be left out of the proposed arrangement. The Ministry of Munitions agreed, and on its request, the Government of India appointed Messrs. Chrestien as their agents, at a monthly remuneration of Rs. 1,000 (April, 1916). The Indian Government arranged to finance their agents' purchases, and forwarded a list of prices which it had been arranged to pay for Government qualities. The prices were :—

Size.	*Clear.*			*Part Stained.*		
	s.	d.		s.	d.	
3	9	2	per lb.	8	4	per lb.
4	6	8	,,	5	4	,,
5	3	9	,,	3	4	,,
6	1	0	,,	0	10	,,

The Minister of Munitions then requested the Government of India to prohibit the export of all available supplies of Nos. 3, 4, 5 and 6 of the two qualities "clear ruby" and "part stained ruby," except by the Government agents. Messrs. Chrestien were to act as selling agents in London, and would themselves finance all purchases in India. The amount of Rs. 25,000, already advanced by the Indian Government for financing purchases, was, the Minister thought, sufficient, and the only further payments which the Indian Government should make were those covering the agents' monthly salary and the expenses incurred. On 10 June, 1916, the export from India of high grade mica, except by the Government agents, was prohibited, a permit for the export of other grades being obtainable from the Chief Customs Officer.

At the request of Messrs. Chrestien, who wished to act as Government agents without remuneration beyond out-of-pocket expenses, the Ministry of Munitions waived the question of salary. In order, however, to cover rail and freight charges, insurance, brokerage and expense of collection, it was necessary to fix a London selling price slightly in excess of the prices paid in India. The prices arranged, therefore, were :—

Size.	*Clear.*			*Part Stained.*		
	s.	d.		s.	d.	
3	10	0	per lb.	9	3	per lb.
4	7	6	,,	6	0	,,
5	4	8	,,	3	10	,,
6	1	3	,,	1	1	,,

As the mica trade required expert knowledge, Mr. Edward Davies, a leading London mica broker, who had no mica mining or manufacturing interests, was appointed broker in London, to report on the quality of all mica shipped on Government account and to distribute it as instructed by the Ministry, being allowed the usual brokerage of 2½ per cent., which was payable by the seller (29 August, 1916).[1]

(c) Efforts to Increase Supplies from India.

The agency arrangement was not very successful. From June to October, 1916, the amount of mica purchased was only 3,524 lbs. of "clear" and 44,032 lbs. "slightly stained," nearly all of which had been furnished by Messrs. Chrestien's mines. It appeared, therefore, that other producers were either not producing mica of Government quality, or were deliberately withholding supplies, or grading down their mica in order to export it to the United States or other countries. In order to meet demands it was necessary for at least three times as much "clear" mica to be produced, and twice as much of all classes of "slightly stained." The Ministry of Munitions, therefore, suggested (18 November, 29 November, 1916),[2] that a second agent should be appointed, in order to alleviate the jealousy of those firms who objected to Messrs. Chrestien & Company being sole Government agents, and encourage them to produce more mica; further, that the export from India of all block ruby mica of every grade should be prohibited, except to London. No export from the United Kingdom would be allowed without the mica being examined by an expert, and no applications to export any mica suitable for Government purposes would be entertained.

In reply to an enquiry from the Indian Government as to the possibility of utilising "clear green" mica (5 December), the Ministry stated that, though it was possible to use it as a last resort in the manufacture of condensers, there were many technical objections, and it was not advisable for the Government of India to collect a supply until it was shown that a sufficient quantity of ruby mica was unobtainable.[3]

On 29 December, the Indian Government reported that the leading firms appeared to be co-operating satisfactorily with Messrs. Chrestien, and it did not appear that there was anything to be gained by appointing a second agent. The Indian Government deprecated an absolute prohibition of export of all grades of block ruby mica except to London, as the higher grades would not be produced in sufficient quantity if the market for the lower grades was restricted. In order to prevent grading down the Government proposed to instruct Collectors of Customs that block ruby of any grade must be submitted to the Government agent for examination before an export licence was granted. It was doubtful, even so, whether the full quantities of ruby of grades required by the Ministry of Munitions would be obtainable. Messrs. Chrestien's standards for clear and slightly stained were considered by other firms to be unduly high, and if slightly lower qualities could be accepted it would mean a substantial increase in the amounts available.

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[1] D.D.G.(A). 10472. [2] C.R.V./I./97. [3] 21 December, 1916.

As it appeared probable that the best quality mica produced by native mineowners was either being hoarded in India for a rise in price or was being illegally exported to other countries, an examination of stocks was begun in February, 1917, under the supervision of Mr. M. A. Mackenzie, a police officer detailed for the work by the Indian Government (14 February, 1917). All persons in possession of mica were required to make monthly returns of all their stocks. Mr. Mackenzie was further authorised to enter and search for stocks in order to test the accuracy of the returns, while the Government agents, Messrs. Chrestien, were empowered to requisition any mica which was being withheld from the market.[1]

On 17 March, 1917, the Government of India announced that an absolute prohibition was imposed on the export of mica of all kinds, ruby and others, including splittings, to all destinations except to the United Kingdom.[2]

(*d*) Termination of the Buying Agency.

Meantime, the shortage of the high-class ruby mica required for magnetos had become more acute in the United Kingdom, while the magneto industry in the United States was flourishing. Messrs. Chrestien's agency had failed to secure satisfactory supplies, and in March, 1917, the Ministry of Munitions asked the Indian Government to terminate it. Indian producers were informed that there was a keen demand for ruby block mica in London for munition purposes,[3] and that all qualities and sizes, both of Government and trade descriptions, might be shipped freely to London without any restrictions whatever, the Government agency having been abolished. Dealers and shippers were advised to have their consignments very carefully sorted before export, whether at Calcutta or up-country, as higher prices were obtainable in London for carefully selected mica of the better grades. Although mica might be consigned freely to any private importer in London, the British Government reserved the right to requisition any consignments on arrival if required for munitions. Shipment might be made under contract for sale to the United States on condition that the cases were shipped *via* London and landed there for inspection, and, if necessary, requisitioned by the British Government. If not required for military purposes in London, re-export to the United States would be permitted. But in no circumstances whatever would direct shipments be permitted to the United States of America, or to any destination other than the United Kingdom.

It was further arranged that for the future, with regard to details and routine matters, the Ministry of Munitions should correspond directly with the Director General of Commercial Intelligence in India, but that communications involving questions of policy should continue to pass through the Government of India and the India Office.[4]

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[1] C.R.V./I/202.
[2] *Ibid.*
[3] 17 May, 1917 (C.R.V./I/202).
[4] *Ibid.*

When advising the termination of Messrs. Chrestien's agency appointment, the Ministry of Munitions was not fully aware of the steps taken by the Indian Government during the last few weeks of 1916, which resulted in the issue in February, 1917, of orders requiring monthly returns and empowering Messrs. Chrestien to requisition stocks.[1] The India Office was therefore informed that had the Ministry been aware of the active measures which were to be initiated from 1 March, 1917, they would not have recommended the immediate termination of the agency appointment, but would have allowed sufficient time to elapse to ascertain whether the new procedure was effective; and that they agreed that Messrs. Chrestien's agency should be continued in a limited form which would permit of the power of requisitioning stocks being employed in connection with any hoarding.[2] Messrs. Chrestien had a capable staff to deal with and sort all requisitioned mica, but Mr. Mackenzie had no expert knowledge and no staff, with the result that over three months elapsed before any appreciable quantity of high-grade mica was received as a result of Mr. Mackenzie's operations.

Messrs. Chrestien, therefore, continued their agency as buyers of Government qualities on Government account, but only on a small scale, until the end of 1917, when the agency fell into abeyance. The prices arranged by agreement with the Government of India remained in force until October, 1917, when owing to increased cost of production an advance of 20 per cent. on the 1916 price list was conceded by the Ministry of Munitions. This was insufficient to meet increased labour costs and the increased cost of coal and machinery,and a further increase to operate from 1 October, 1918, was sanctioned subsequently. In order more adequately to control and distribute mica as it came forward the Director General of Commercial Intelligence, India, was instructed to forward summaries of the visible supplies reported monthly by the mine owners and of the quantities of block mica and splittings at the docks awaiting shipment.[3]

(*e*) Effect of Control by the Government of India.

The issuing of the orders in February and other steps taken by the Indian Government had the effect of easing a situation that earlier in the year had been most precarious.[4] Inferior quality ruby mica shipped to London for further sorting and splitting yielded from 10 to 25 per cent. of plates equal to Government standard quality. British requirements, however, and French requirements, which had never been met satisfactorily, were rapidly increasing. The American Government were also beginning a large programme of aeroplane construction and would require an enormous quantity of mica for magnetos and condensers. It was essential, therefore, that Indian output of mica should be increased to the greatest possible extent. In order to make the best use of the limited output, it was necessary for mica slabs to be more thoroughly split, as block mica, more or less obscured by rust or vegetable stain, generally contained an appreciable

[1] See above, p. 165. [2] C.R.V./I/202. [3] C.R.V./I/202. [4] C.R.V./I/97.

percentage of sound laminæ sufficiently thick for condenser plates. Miners and dealers were also encouraged to sort more carefully the size and quality, as from examination of splittings on arrival in London it was apparent that a quantity of block mica had been used which with more careful sorting and splitting would have yielded plates of good quality. Skilled labour in London for this work was limited, while the cost and delay was great ; therefore, it was work that could best be performed in India. At the same time the Ministry decided to accept " trade gradings " of clear and slightly stained mica.

(*f*) INCREASED REQUIREMENTS FOR 1918.

With increasing demands being made upon the London market, an effort was made towards the end of 1917 to find out the requirements of the Allies, but no definite data could be obtained. The French, who were large users, could only reply that their purchases were made through London brokers. A French representative who was buying about 20 tons per month on the London market, had no knowledge of the ultimate consumers, for what use it was intended, or the quality required. In the same way Italy, which bought a small quantity from the Argentine and Brazil, but purchased the remainder through London brokers, had no figures of the actual requirements for 1918. Neither could America furnish any figures, but in order to obtain some measure of control over American magneto manufacturers, the American authorities at once accepted a scheme put forward by the Ministry of Munitions whereby all mica entering America was taken over by the Navy Department and retained if required for munitions, the purchaser being refunded his purchase price, which was the same as that paid by English magneto manufacturers on the London market. Though no definite figures as to Allied requirements were forthcoming, the Department was enabled by licence and otherwise to control supplies and price through the medium of the London mica market. Actual shipments from London to the Allies during 1918 were :—

America	15,400 cases
France	13,277 ,,
Italy	2,515 ,,

Unfortunately the inability to furnish definite figures for requirements was not confined to the Allies. From 1916 onwards practically all the mica produced was used for munition purposes, but owing to the varying but rapidly increasing demands for mica for aircraft and wireless work and for compass cards for the Admiralty, it was never possible to gauge, with any reasonable degree of accuracy, the requirements for any length of time ahead. The nearest approach the Department ever got to a definite figure of requirements, was late in 1917, when at a conference with the Air Board it was estimated that 100,000 magnetos would be required for the aircraft programme alone during 1918. It was estimated that to meet this programme together with requirements for wireless and for the Admiralty, 120,000 cwt. cases of mica would be required, which was approximately equal to the estimate of the world's production for 1918. The Air Board insisted

that all magnetos for its programme should be manufactured only from the best quality mica, and as first quality ruby mica only averaged 5 per cent. of the total production, and each magneto required about 200 plates, the world's production would not give a sufficient quantity to carry out the Air Board's programme. Experiments under the auspices of the Mica Section were at once conducted, and a process evolved by which all air exclusions were able to be removed from inferior or slightly stained mica. But although tests of magnetos made from inferior mica so treated showed that the magnetos were in every way the equal of magnetos made from first quality ruby mica, it was only absolute necessity that compelled the Air Board to accept them. The acceptance of this treated inferior mica doubled the supplies of mica available for magnetos without any increase of mica production. This, together with the rigid control over Indian supplies and the increase in shipments of first quality mica, enabled the Department to supply all the mica required for the 1918 programmes, both for Great Britain and the Allies,[1] with an importation of 72,000 cases, though it was originally estimated that the British demands alone would require a production of 120,000 cases.

At the same time steps were taken to ensure that all No. 1 quality of certain sizes of ruby mica should pass only to those contractors who had contracts with the Air Board and Admiralty. A Control Order under the Defence of the Realm Act was therefore issued on 15 April, 1918, which prohibited dealings in mica except by licence. No person could take delivery of clear and partly stained ruby mica of best or "Government Standard," or suitable for the manufacture of magneto condensers plates in sizes No. 3 to 6 inclusive. Under this Order persons requiring mica of such quality and size had to forward the contract with the Air Board or Admiralty, as the case might be, to the Director of Mica Supply, and an authorisation for the purchase of such mica was given to the intending purchaser, a similar authorisation to sell being forwarded to the broker to whom the order was allocated.

(*g*) The Mahesri Mines.

Meantime, the Indian Government had been making further efforts to increase supply. The Mahesri mica mines, yielding perhaps the best quality ruby mica in India, were situated about 14 miles west of Jha Jha Station, on the East Indian Railway, in the province of Behar and Orissa. The property, however, was in the hands of "a multitude of impecunious, pugnacious, and unreliable owners," and owing to litigation, there was little or no output.

Faced with the absolute necessity of immediately increasing Indian mica production the Government of India decided to requisition the land covering the area of the deposits (under the Defence of India Regulations) and entrust the working and developing of the mines to Messrs. Bird & Company, a well-known Indian firm of mica mine owners and brokers. An agreement was accordingly entered into with Messrs. Bird by the Government of India on behalf of H.M. Government,

[1] 21,500 cases were re-exported to the Allies.

early in 1917, which provided that Messrs. Bird were to work the mines and ship the mica output to London, where it would be sold as Government mica. A sum for capital expenditure was to be advanced to Messrs. Bird, the intention being that the outlay and capital expenditure on development of the mica could be recouped, or at least partially recouped, through profits arising out of the sale of the mica. For this purpose the Indian Government advanced Messrs. Bird Rs.2,00,000—equal to about £15,000—and Treasury sanction was obtained for the payment of £20,000 to the Indian Government, to include this £15,000 and other miscellaneous charges connected with mica operations other than those connected with the Mahesri mines.[1]

Operations were commenced by Messrs. Bird early in 1917, and a statement submitted by them for the twelve months ending 31 March, 1918, showed that the amount advanced by the Indian Government was Rs.71,850, while Rs.54,403 had been advanced by the firm. Capital expenditure amounted to Rs.11,627, while working expenses totalled Rs.88,122, of which Rs.14,272 was for mining establishment and Rs.38,607 for mining labour. The total value of the mica mined for the twelve months was Rs.48,051.

As it appeared from this statement that heavy expenditure had been incurred in opening and developing the mines, which might not be entirely repaid out of the net profits from the sale of the mica, the Ministry of Munitions asked whether the Government of India had taken, or were taking steps, to obtain a charge on property for the excess of any such Government expenditure, such charge to be continued after the period when the mines had ceased to be worked by the Government of India, but the Viceroy stated that the mines had been requisitioned under the Defence of India Act, which did not allow of obtaining a charge on the property as assumed by the Ministry of Munitions. It was anticipated, however, that the value of the mica would more than cover working expenses, that the cost of machinery would be almost entirely recouped by sale when mining operations ceased, and that the eventual loss would mainly represent outlay on buildings.

At the same time the Viceroy pointed out the immediate necessity for increasing the credit to Messrs. Bird & Company for capital expenditure by a further Rs.4,00,000 (£30,000):—"unless sham hoistings and pumping plant can be put in at once, before the rains, output of Mahesri Mines cannot be maintained in rainy weather and further development will be impossible . . . Bird's are not prepared to continue unless they receive this credit. As Ministry of Munitions throughout emphasise importance of obtaining good quality mica, in particular Mahesri mica, we have, owing to immediate urgency, assumed Ministry of Munitions will accept proposal and have ordered increase Bird's credit to Rs.6,00,000." Treasury sanction for the repayment of the additional amount advanced by the Indian Government to Messrs. Bird was granted on 26 July, 1918.[2]

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[1] D.D.G.M. 1179. The India Office do not appear to have received this amount. One of the main files cannot be found.

[2] D.D.G.M. 1179.

The Ministry of Munitions had urged that the property might be retained by the Government of India for such time as might be necessary to avoid the loss on the buildings by obtaining further profits from the sale of the mica (31 January, 1918). If the mines were closed down a considerable financial loss to the Ministry of Munitions would result. When the Armistice was signed the policy of continuing to work the mines was debated. On the one hand, it was doubtful whether the mines were a paying concern, and from a financial standpoint the best solution appeared to be to stop the mines and sell the machinery, though this would involve an immediate financial loss. On the other hand, although the necessity for supply had disappeared, the question had to be regarded from a key industry point of view. If the mine was closed down as a Government proposition, it was doubtful whether it would continue to be worked owing to the disputed ownership of the minerals. But it was doubtful what power the Government of India had to retain the property after the war. The Defence of India Act, 1915, only remained in force for the duration of the war and six months after. Possession might perhaps be taken by the Indian Government under the Land Acquisition Act, 1894, if they were prepared to direct that it was for a public purpose, i.e., in pursuance of a general scheme for making India self-contained with regard to munitions of war. An alternative scheme put forward by the Controller of Commercial Finance (25 November, 1918) to recoup the loss or some portion of it, was that a company should be formed in India and shares equivalent to the Government capital expenditure should be allotted to the Government, and shares equivalent to the disputed owners' property in the mines allotted to those owners. The shares to be allotted to the Government would only be taken with the intention of selling them.[1]

The Viceroy recommended on 5 February, 1919, that operations, both at Mahesri mines and at Masnodih, a small mica mine worked by the Government of India, should at once cease.[2] The deeper reefs which had been opened at Mahesri proved extremely disappointing in quantity, quality and size of mica. The mine was being run at a loss of Rs.20,000 per month, and the loss would only be increased if the enterprise was persisted in. Even assuming that it was a public purpose to make India self-contained in munitions of war, the Land Acquisition Act could not be applied, as the output of the mine was not considered necessary to that end, while acquisition by private treaty was impossible owing to disputes of ownership. The Masnodih mine was a small one, the output being only about five tons of mica per month, and though the working of the mine showed a small profit, the services of the geological officer in charge could be more usefully and profitably employed elsewhere.

The Viceroy pointed out that conditions were favourable for the sale of the machinery and plant at the mines ; also that its removal might be delayed by the monsoons if not undertaken quickly, and he urged an early decision, as delay would only occasion further losses. The statement of accounts forwarded by the India Office showed that a

[1] D.D.G.M. 1179. [2] *Ibid.*

loss of over £13,000 had been sustained in the working of the Mahesri mines up to 30 June, 1818. The value of mica won during the period covered by the statement was approximately £4,800, against charges for mining labour alone of £8,057.

These arguments were accepted by the Ministry, and the Government of India was asked to stop all work at once, and to sell the plant and machinery at the highest prices obtainable.

(*h*) MICA FROM OTHER SOURCES THAN INDIA.

Prior to 1917 nearly all the mica imported to this country was mined in India. The most promising source of new supplies was German East Africa, and following upon British occupation of the territory in 1916, steps were taken with the sanction of the Colonial Office to work the mica deposits there. Two engineers with expert knowledge of mica production were sent out by the Ministry of Munitions early in 1918, and regular consignments were received during the year. A certain amount of mica was also imported from South America. Imports from countries other than India from January, 1917, to January, 1919, totalled 4,068 cases, made up as follows :—

	Cases.
(German) East Africa	2,014
South Africa	159
South America	1,057
Canada	706
Ceylon	128
Norway	4
Total ..	4,068

(*j*) POST WAR CONTROL.

The control of mica did not terminate after the Armistice, as it was regarded as a key industry, being a material absolutely vital to the electrical trades. On the cessation of hostilities English electrical industries had attained a high state of efficiency and had displaced Germany and Austria from the high position those countries held before the war, and still further demands for mica were anticipated with the development of commercial aircraft and wireless. Competition from America, which was developing considerable sources of supply in Brazil and the Argentine, was anticipated, and arrangements were made to stimulate production in India, Nyasaland and Ceylon. It was recommended that the Indian Government should retain the control of mica for five years, that idle mines should be developed and assisted with machinery and stores, and that the classification and examination of mica in India should be improved.

IV. Oxygen.

Some six years before the outbreak of war, the Brin process of obtaining oxygen for industrial purposes by the use of barium oxide was supplanted by newer processes, devised by Linde and Claude, dependent on the liquefaction of air. The British patents for these

were held by one firm, the British Oxygen Company, who thus had a monopoly of practically the whole supply of oxygen available in the United Kingdom when the war broke out. This monopoly the firm was anxious to keep, and the only other company which installed plant to produce oxygen was bought up by the older company after a very brief existence, during which, however, they sold at a price about half that of the established firm.[1]

In 1914 the British Oxygen Company owned eleven factories, which were capable of producing altogether 750,000 cubic feet per day. During the next three years the nominal production was worked up to 1,000,000 cubic feet per day, and the actual output in 1916 averaged 3,000,000 cubic feet per week, practically all of which was used for munitions purposes. Requirements, however, increased even more rapidly, and by the winter of 1916–17 exceeded available supplies.

The chief demand for oxygen was for oxy-acetylene welding and cutting at steel works and shipyards, and the Admiralty was by far the largest consumer during the earlier years of the war. A small proportion of the total output was used for medical purposes and for mine rescue apparatus, and supplies were also required for bomb manufacture at Woolwich, and for aircraft. After 1914, two or three small additional sources of supply were developed to cope with the increasing demands. Plant was set up in 1916 at Hadley, in Staffordshire, under the organisation of the Oxygen, Hydrogen, and Nitrogen Gases Company, for a new process worked out by Professor Pictet. This process was to produce pure oxygen and hydrogen simultaneously, which could not be done on the Linde and Claude plants, but it was still in an experimental stage and had little appreciable effect in increasing supplies. Small plants had been set up in the Tyneside and Durham districts just before the war in connection with mine rescue work, but the apparatus was of German make, and unfamiliarity with its details prevented the workers from obtaining any adequate output. The Liquid Air and Rescue Syndicate, Ltd., had small works at Willesden, but the only source of supply which was utilised to any extent besides the British Oxygen Company was the Royal Aircraft Factory at Farnborough, where oxygen was produced as a by-product in the manufacture of hydrogen.

In February, 1917, the output of bombs at Woolwich was seriously affected by the shortage of oxygen, while at the same time delays were occurring in repairing ships for the same reason. Consequently, in May, 1917, the Advisory Committee decided that the Trench Warfare Supply Department should take over the control of oxygen. It appeared, however, that the real difficulty did not lie in inadequate plant for the production of the gas. The British Oxygen Company was erecting new plant to provide for an additional 250,000 cubic feet per day,[2] and the 5,500,000 cubic feet per week which would then be produced by the firm, together with the 250,000 cubic feet per week which was expected from the Staffordshire plant, would cover requirements.[3] The two

[1] A.C. 99. [2] *Ibid.* [3] W. 360.

factors actually limiting supply were shortage of cylinders and of labour.[1] In September, 1917, therefore, the Ministry agreed with the Admiralty that control of manufacture was unnecessary, particularly as there was practically only one source of supply, but it was essential that the allocation should be by one central authority. A committee of representatives from the Admiralty and Ministry of Munitions was formed for this purpose, which was also to be responsible for the stock of cylinders. Owing to the time which elapsed between the despatch of filled cylinders and their return empty to the works, a stock sufficient to hold 2½ weeks' supply of oxygen was needed. As the number in use was already insufficient for this purpose, in view of the plant extensions to be started up, 33,500 new cylinders of 100 cubic feet capacity were required at once. The shortage had been increased by the fact that the Admiralty took the whole output of the two tube-making firms of the country, and had in addition borrowed cylinders from the Oxygen Company for transport to Malta and the West Indies. Orders were accordingly placed for the additional cylinders required, and the Oxy-acetylene Committee dealt from this time with the allocation and distribution of the gas to all Government Departments and firms requiring it. The comparative demands for different war purposes may be gathered from the following table,[2] representing the allocation of output during a typical fortnight in the summer of 1917 :—

	Per cent.
The Admiralty	59·1
Aircraft Works	11·0
Steel Works (including guns, shells and motor transport)	14·3
Factory Plant Repairs	8·0
Trench Warfare Department	4·8
War Office Contracts (for boots, shoes, machinery, etc.)	1·7
Medical Purposes	1·1

In order to conserve all available supplies for purposes of national importance, the Admiralty, as the largest user, issued a control order under the Defence of the Realm Regulations on 17 December, 1917, requiring returns of all available stocks, and prohibiting the sale or supply of oxygen except in accordance with the instructions of the Director of Materials and Priority.

In 1918 the chief problem was the supply of oxygen to the medical services and the Air Force. With the increase in gas warfare the need for oxygen, which was extensively used for the treatment of gassed casualties, was much increased. Until 1918 British hospitals had been supplied by the British Oxygen Company, and hospitals and clearing stations in France by French firms. It was difficult to obtain any clear estimate of medical requirements, as in the past use had always been limited by the supplies available. A severely gassed case, it was estimated, would use 700 gallons of oxygen, and an ordinary case 150 gallons, while for general anæsthesia 10-30 gallons were used for one man according to the apparatus in use. Supplies had long been inadequate for normal uses, while it was desired in 1918 to develop the use in France of oxygen with nitrous oxide for producing anæsthesia.

[1] A.C. 99. [2] W. 360.

In February, 1918, a scheme for the establishment of a plant to produce liquid oxygen at selected points close behind the line, from which it could be conveyed in special containers to the various hospitals and casualty clearing stations, was drawn up. The Air Ministry was installing plant in France to produce hydrogen, which would give 120,000 cubic feet of oxygen a week as a by-product, of which the greater part would be available for medical needs.[1]

In 1918, a development was made in the use of liquid oxygen in aircraft,[2] and, in March, the Oxygen and Hydrogen Sub-Committee of the War Priorities Committee took over the responsibility for providing manufacturing capacity, while it was left to the Air Ministry to place contracts.[3] The needs of the Royal Air Force were steadily increasing, and for home service part of the British Oxygen Company's plant at Wembley was used to produce liquid air until other plant, in course of erection for the purpose, was completed. The price asked by the firm, however, was extremely high, being based on old methods of production, and in no way applicable to the new process.[4] Supplies for use in France had to be obtained in that country, as transport was impossible owing to evaporation.

In July, 1918, further attempts were made to co-ordinate the activities of the various authorities interested in oxygen. The Oxy-acetylene Committee, which had formerly dealt only with gas, now took over the allocation of liquid oxygen,[5] and it was decided that all surplus output above their own requirements from the plants administered by different Departments should be placed at the Committee's disposal. To co-ordinate the different aspects of research as to the use and production of oxygen and liquid air, the War Production Committee appointed a Central Research Committee, composed of representatives from the Admiralty, War Office, Air Ministry, Ministry of Munitions, Home Office, the Department of Scientific and Industrial Research, and the Medical Research Committee of the National Health Insurance Commission.

V. Resin.

Under normal conditions resin is chiefly used in the manufacture of soap, soluble oils and greases, in paper-making from other material than wood pulp, and in paints, varnishes, etc. In connection with the manufacture of munitions of war it was used as a matrix in shrapnel shells, in making artificial rubber for the Admiralty, and in coating ammunition boxes.

The average importation of resin, which was obtained chiefly from France and the United States, into the United Kingdom before the war was approximately 90,000 tons per annum. During the first eleven months of 1917, imports into the United Kingdom totalled 84,000 tons, and it was not until the latter months of that year that there was any difficulty with regard to supply. There had up to this time been no interference with the trade, which had carried on under

[1] D.M.R.S. 307A. [2] C.R.V./Gen./0533. [3] D.M.R.S. 307A.
[4] C.R.V./Gen./0533. [5] C.R.V./Gen./1595.

pre-war conditions, and it was only on a complaint from the Coal Controller of a shortage of resin for the manufacture of colliery grease that the supplies and requirements of this material were brought to the notice of the Materials Department of the Ministry of Munitions.

As the result of a series of conferences with leading members of the trade, it was found that the question was really not a shortage of supplies, but one of price.[1] From a pre-war price of £4 to £6 per ton on wharf in the United States, the price had risen by leaps and bounds, the price in America being about £13 per ton at wharf, while it was selling at from £62 to £65 per ton in the United Kingdom (December, 1917). There was much speculation going on, and the price promised to reach still higher limits unless strong action was taken. Stocks in the United Kingdom totalled 17,690 tons, and as the Ministry of Shipping had decided to stop all private shipments from January, 1918, it became necessary for the Ministry of Munitions to assume control.[2]

The annual consumption was estimated as follows :—

	Tons.
Shrapnel (as a matrix for shells)	12,000
Colliery grease and lubricating oil	5,000
Soap	30,000
Paper and cardboard making	22,000
Paints, varnishes, printers' ink, etc.	21,000
Total	90,000

Stocks in this country in January, 1917, so far as could be ascertained, were :—

	Tons.
Soapmakers	9,700
Wharfingers :—	
Earmarked for shrapnel	2,000
General Stocks	4,490
In hands of Admiralty Marshal	1,500
Total	17,690

Thus the stocks represented about two-and-a-half months' requirements, and as there was little possibility of economy in any direction, the Controller of Non-Ferrous Materials proposed that the Shipping Controller should make provision for shipping resin from America at the rate of 45,000 tons per annum (29 January, 1916).[3] It was fully realised that this might involve a reduction of tonnage available for important war material, and even for food, but it was absolutely essential that collieries, glycerine plants, and paper mills should be kept in commission.

While conducting an investigation into the position the Controller had taken the necessary steps to ensure supplies for grease manufacturers for colliery requirements. As the result of a series of conferences with the trade the lines on which the Ministry was to exercise its control were laid down (9 January, 1918).[4] The Ministry of Munitions was to import the whole of the material ; it was to distribute

[1] Report by Sir J. Eaglesome. (Sir L. Llewelyn's Papers, 684.)
[2] C.R.V./Gen./1761. [3] Sir L. Llewelyn's Paper 684. [4] *Ibid.*

supplies to the principal importers in proportion to their individual imports in 1917, a margin of profit on the imported cost was to be agreed upon and the Ministry was then to fix the commercial price. Distribution to users was to be carried out by the importers without disturbance of existing conditions. The order subsequently issued (21 January, 1918), brought under Ministry control all resin and resin oil, whether in stock or transit, and no dealings were allowed except under license from the Ministry.[1]

The Resin Distributors' Association agreed to take delivery of all resin coming into the United Kingdom,[2] acting as distributors for the Ministry at a brokerage fee varying from 1 per cent. to 3 per cent. Under this agreement the selling prices fixed by the Ministry varied from £55 to £57 10s. (ex store) for American resin, French and Spanish resin being £1 per ton less. The Association guaranteed the Ministry against any loss in the collection of amounts due from customers, and the agreement was subject to three months' notice on either side. Under this agreement a profit of over £300,000 was made by the Department.

Imports of resin from France during 1916 were 14,500 tons, but owing to the greatly reduced French production imports from this source were, by order of the French Ministry, cut down to 550 tons per month during the latter part of 1917, but after the situation had been explained by Sir Charles Ellis, arrangements were made to increase supplies to 15,000 tons per annum, at a price not to exceed 82 francs per 100 kilos.[3] Transport of this resin was arranged through the American Transportation Department in Paris, tonnage space being reserved for resin shipments in American steamers returning to the United Kingdom after discharging coal cargoes in France.[4] Contracts for 28,000 tons were placed in France, at an average of £36 2s. 8d. (in store in the United Kingdom), but on the cessation of hostilities orders for 10,000 tons were cancelled.

The purchase of 21,000 tons, or six months' supply of resin in America subject to freight being available, was sanctioned by the American Board in London and by the Treasury in March, 1918,[5] and tonnage allocation arranged with the Shipping Controller. Treasury sanction was also given for a further purchase of 10,000 tons,[6] and both purchases were forwarded to the British Purchasing Mission in America for negotiation.

Large stocks were held in America[7] by Messrs. Lever Bros., of Port Sunlight, and the firm agreed to release 17,000 barrels (approximately 3,047 tons) to the Ministry at a cost price plus insurance, interest and storage charges, which worked out at about £18 per ton ex-warehouse, as compared to the market price of £24 per ton. This purchase not only effected a saving of £18,000 to the Ministry but

[1] C.G.A./Gen./62. [2] C.M.3/6. [3] M.S. 1135.
[4] (Printed) *Weekly Report*, No. 131, IVB (23/2/18).
[5] *Ibid.*, No. 149, XI (6/7/18).
[6] *Ibid.*, No. 151, XI (20/7/18).
[7] C.N.F.M.S. 684.

enabled the Purchasing Committee to keep off a rising market to that extent. It is interesting to note that this same stock of resin was subsequently resold to Messrs. Lever at a price which showed a big profit to the Ministry. Altogether 32,000 tons were bought in America at an average cost (in store in the United Kingdom) of £30 18s. 6d.

In January, 1919, Ministry stocks and commitments approximated 38,000 tons valued at over £2,000,000, and acting on the policy adopted by the Disposal Board of liquidating all stocks as rapidly as possible, tenders were asked in April for about 10,000 tons. The tender prices ranged from £27 to £35 per ton, and as this was less than cost to the Ministry, and much lower than ruling market price, tenders for 3,000 tons only were accepted. This method of disposal was not, therefore, proceeded with, and sales by personal negotiation were made instead.

On 30 June, 1919, Ministry stocks had been reduced to 6,874 tons, valued at approximately £300,000. Three months later (15 September, 1919) the Ministry stocks of approximately 4,280 tons were sold to the Resin Distributors' Association at the market price of the day, and even at this price the transaction showed a profit to the Ministry. The control Order issued on 31 January, 1918, was suspended as from 18 March, 1919.

VI.—Shellac.

The supply of shellac was not controlled by the Materials Department until 1918. Before that date all requirements were secured by Contracts Branch P.C. 9, from India, which supplies the whole of the world's production. During 1917 about 1,280 tons of shellac, which is used in electrical and installation work, in the manufacture of varnish, and in the making of gramophone records and discs, were imported, and of this Government Departments and manufacturers absorbed approximately 1,000 tons.

By arrangement with the Government of India 20 per cent. of the shellac exported from Calcutta was consigned to the Ministry of Munitions at a price of about £84 per ton in Calcutta. On arrival in this country 40 per cent. of these imports were set aside for the use of the Allies, to whom it was sold at a price of £105 per ton; the remainder was invoiced to Government Departments at £105 per ton and contractors holding Class A certificates at £144 per ton.

Before the war the normal price of shellac was £60–80 per ton (*ex* store) in London, but owing to speculation the price during the latter months of 1917 and the early part of 1918 was forced up to a prohibitive figure, no less than £460 to £500 per ton being asked in March, 1918. The position of the Ministry at this time was that about 600 tons were held in stock, this being approximately six months' requirements for Great Britain and the Allies.

The situation thus created arose entirely through lack of freight from Calcutta to the United Kingdom. When it became known that the Ministry of Shipping had decided to restrict freight from Calcutta speculators seized the opportunity to force up the price. Many firms had sold shellac for delivery three and four months ahead, as they

held covering stocks in Calcutta ready for shipment. Moreover, they had the promise of the Shipping Controller that certain freight space would be allocated them. This promise under extreme pressure of circumstances was subsequently withdrawn, and the interested firms were faced with the prospect of paying the exorbitant prices asked for by holders of shellac in this country in order to meet their commitments. The principal holders of shellac in this country seized the opportunity to " corner " the material. On 2 January, 1918, the spot price was 360*s.* per cwt.; on 1 February, 390*s.*; on 11 February, 425*s.*; and 500*s.* was quoted a week later.

In this extremity an almost universal appeal was made to the Ministry of Munitions by the " bears." If no help was forthcoming several firms would have been ruined, and though the Ministry had no sympathy with either " bulls " or " bears," it was felt that the penalty of bankruptcy was too severe. The London Shellac Association was urged to arrange an amicable settlement by agreement, but no agreement was reached, and as consumers were being forced to pay the high prices ruling for shellac an Order for the control of the material was issued (12 March, 1918).[1]

By the terms of this Order all persons holding, or having under their control, any shellac were called upon to furnish a return, containing full particulars of all shellac held by them, the grades, and the purpose for which it was intended to be used. Holders were also requested to furnish the average consumption during 1917. Further, under the Order, no person was allowed to purchase, sell, deliver, or supply any shellac except under and in accordance with the terms of a licence issued by the authority of the Minister of Munitions. No licence, however, was required for the purchase of a quantity not exceeding an aggregate of 7½ cwt. per month; neither was a licence required to make delivery against any contract in writing existing prior to the issuing of the Order, but it was necessary to hold a licence to purchase for such a contract.

The quantity of shellac required by the general body of consumers was comparatively small, and owing to the high price they kept off the market until absolutely bound to enter. The result of the Order, therefore, was that speculation in the material practically ceased, business being confined to legitimate purchases for immediate requirements.[2]

The returns made by holders in accordance with the terms of the control Order revealed the fact that stocks in the United Kingdom totalled 2,684 tons, with an average monthly consumption of 226 tons.[3] The largest holders were the Government with 814 tons; importers and dealers held 654 tons, and 534 tons were held by gramophone records producers. Arrangements were made to put on the market if necessary, 4,800 cases of shellac of enemy origin then vested in the Public Trustee.[4]

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[1] D.D.G.M. 1148.
[2] C.N.F.M.S. 140.
[3] (Printed) *Weekly Report*, No. 137, IVA (13/4/18).
[4] C.N.F.M.S. 140.

Shellac at this period cost Rs.94 per maund in Calcutta, and could be imported into the United Kingdom at £275 per ton. The selling price had, through Ministry action, been reduced to £425 per ton, but the "bulls" were making at least £150 per ton profit. The London Shellac Association was urged by the Ministry to come to agreement with regard to the speculative May contracts, failing which, the Ministry would not grant any licences for buying shellac for May, or any other delivery, except in the case where the purchaser was a consumer requiring the shellac for use in his works. The Association agreed under pressure (28 April), and the speculative dealings in shellac were finally closed. On the one hand the "bears" had been let off without suffering too great a penalty: on the other, the "bulls" were not permitted to reap the spoils accruing from a corner engineered by them entirely as the result of a lack of transport from India to the United Kingdom.

Under the control exercised by the Ministry, consumers benefited by being assured of supplies at a reasonable price, which had been reduced from 460*s*. per cwt. on 12 March, when the control Order came into force, to 332*s*. 6*d*. per cwt. at the end of August for T.N. Standard. Arrangements were also made with the Ministry of Shipping to allocate space for 125 tons monthly on Government account, and for 200 tons for commercial purposes.[1]

At the end of September, 1918, stocks in the United Kingdom aggregated 3,321 tons, the holders being:—

In Government store on Ministry account ..	1,003 tons.
Importers and dealers	1,463 ,,
Consumers	855 ,,

Following the Armistice, the arrangement made with the Indian Government that 20 per cent. of all exports should be consigned to the Ministry of Munitions was rescinded. Stocks in the country on 30 November, 1918, totalled 3,700 tons, of which 1,300 tons were Ministry of Munitions holdings in Government store, and the disposal of which had to be arranged in such a way as not to injure the trade in the United Kingdom, and also not affect the interests of the Indian export trade.

It was the aim of the Department to liquidate the stocks as quickly as possible, and as nearly as possible at the market rate, which at the time was about £330 per ton for T.N. Standard. It seemed certain, however, that if the whole or a large proportion of the stocks were suddenly launched on the market prices would fall by at least 30 per cent., and the Government would suffer a corresponding reduction in profit accruing from the very advantageous arrangement with the Government of India, under which Government shellac cost approximately only £100 in store in the United Kingdom. The method of gradual disposal was therefore adopted.

It was recognised that the Control Order should be suspended, and this took effect as from 13 December, 1918.

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[1] C.N.F.M.S. 140.

The procedure of disposal decided upon after consultation with the trade was to arrange fortnightly sales of about 250 tons, with a limit price; dealers to be invited to participate *pari passu* with the Government in such sales.

Notice of the method of disposal proposed to be adopted was given publicity in the press, and through this means the fact became known in India. Objection was promptly taken by shippers, whose contention was that such sales would prejudice their market. Their view received the support of the Government of India, which urged (13 December, 1918) that shellac had been supplied to the Government at Rs.42 per maund, while the market price had ranged from Rs.90 to 100, and that it was unfair to upset the market by offering a larger quantity of this cheap shellac, while the shippers had large stocks unsold, which they had bought at market prices.

The India Office demurred, reminding the Ministry that in December, 1916, the Department had asked to be supplied with shellac "for the use of the National Factories and Government Contractors in this country." No arrangement, Mr. Montagu pointed out, was made for the re-sale of shellac not required for the use of the national factories and Government contractors, and such a re-sale as was contemplated by the Ministry involved a departure from the agreement entered into with the Government of India in January,1917, "and should not, in fairness to the Government of India, be made without their consent."

In reply, the Minister of Munitions urged that the exporters had recouped themselves for the cession to the Government by increasing prices for the remainder of their exports, and that some of the firms who were now complaining had engineered the "most regrettable corner" in shellac in 1918, which caused the price to reach £500 per ton, and which was only brought to a close under pressure by the Ministry of Munitions.

The whole of the Government stocks were disposed of during the next six months at prices varying from £140 to £365 per ton, the principal purchasers being dealers to whom a reasonable profit had to be allowed. On the sale of the 4,360 tons of shellac a profit of about £250,000 was realised.

VII. Calcium Carbide.[1]

The calcium carbide needed for lighting, cutting and welding was obtained without difficulty until early in 1917, when demands for war purposes greatly increased. The sources of supply were three:—the British Carbide Company, of Manchester, the Canada Carbide Company and the Alby Carbide Company. The last firm had hitherto provided the bulk of the supplies from Norway, but as foreign supplies were precarious and freights high, it was decided to develop home production. The British Carbide Company, under an assisted contract with the

[1] For a fuller account see HIST. REC./H./1860/7.

War Office, were in 1917 producing about 100 tons a month. They agreed to make extensions for an additional 250 tons a month within four months, and received a grant for the purpose. The extensions were not complete till May, 1918, and the total output between October, 1917, and December, 1918, estimated at 16,250 tons, was only 3,280 tons. It was therefore necessary to continue overseas contracts. The Canada Carbide Company, which had taken War Office and Admiralty contracts for 5,000 tons, contracted in 1917 and 1918 for a further 15,000 tons; while from the Alby Carbide Company, 10,000 tons were ordered in October, 1917, 15,000 in December, and 7,500 in October, 1918.

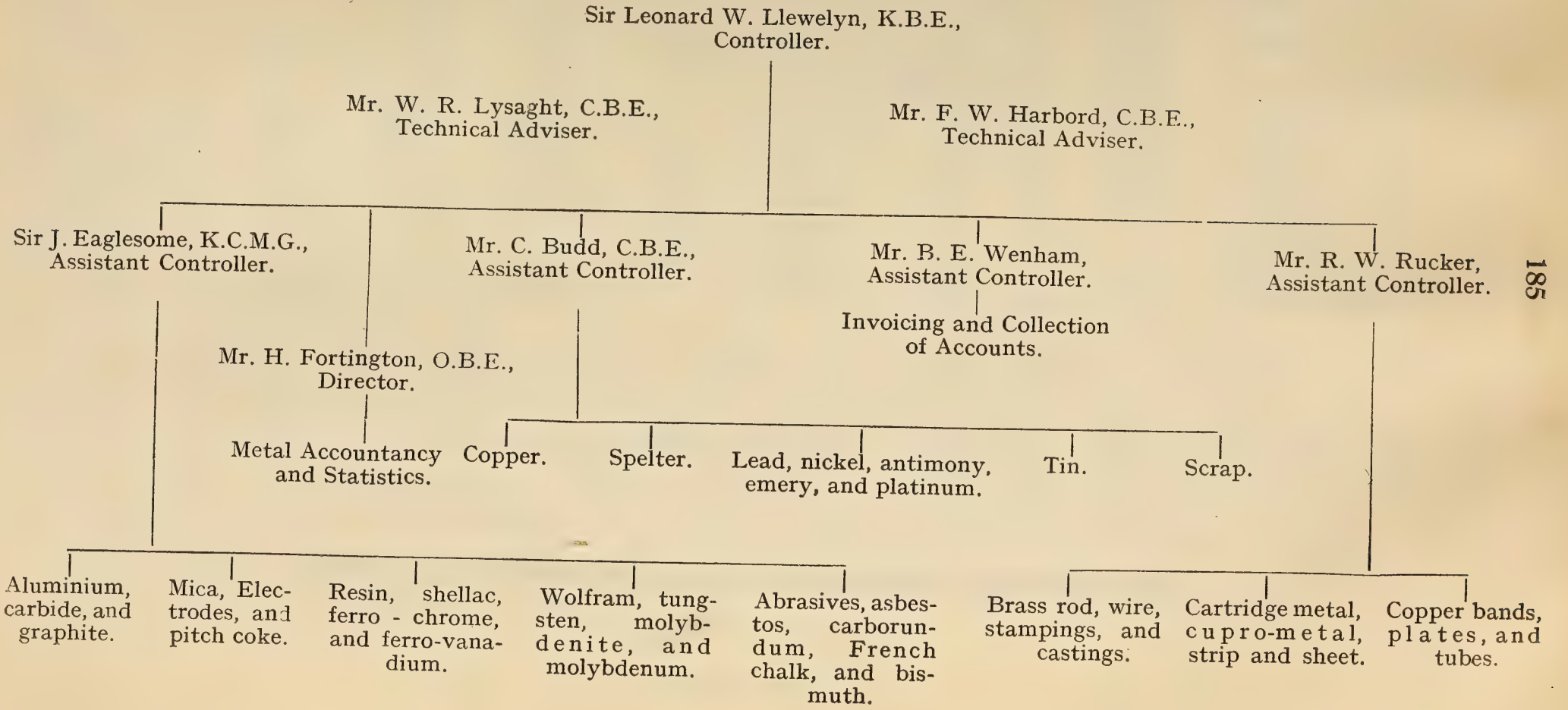
Control of stocks of carbide was taken by an Order of 24 September, 1917, which also prohibited dealings without permit and required returns. Prices were also controlled, the maximum allowed being several times revised, and varying from £25 to £45 a ton. The permit system was abolished on 1 December, 1918.

APPENDICES.

APPENDIX I.

(CHAPTER I., p. 8.)

Organisation of the Non-Ferrous Materials Department, 1 November, 1918.



APPENDIX II.

(CHAPTER I., p. 4.)

Supply, Consumption, and Value of Non-Ferrous Materials, 1917.[1]

	PRODUCTION.			Imported Ore.	Consumption.	APPROXIMATE VALUE.		Countries of Origin.
	Home.	Imported.	Total.			Pre-War.	Present.	
Aluminium ..	7,183	15,261	22,444	—	16,259	£80	£225	U.S.A., Scandinavia.
Bauxite ..	—	—	—	24,000	24,000	—	—	France.
Cryolite ..	—	—	—	413	413	—	—	Denmark.
Antimony ..	11,875	7,550	19,425	19,326	10,462	£30	£85	Argentine, Chile.
Calcium Carbide	2,500	20,958	23,458	—	30,000	£12	£35	Norway.
Copper	35,607	283,219	318,826	—	305,800	£72 (Average best selected)	£134	U.S.A., Spain, Australia.
Electrodes ..	2,400	3,960	6,360	—	5,340	Carbon, £16 Graphite, £40	£45 £116	U.S.A., France, Sweden.
Emery	—	8,518	8,518	—	8,518	£21	£27	Greece.
French Chalk ..	—	12,785	12,785	—	12,785	£3 10s.–£6	£10–£14	France.
Graphite ..	—	11,052	11,052	—	10,000	—	£100	Ceylon, Africa, India, and Straits.
Mica	—	1,924[2]	1,924	—	640	5s. 10d.–8d. per lb.	£45 17s. 6d.—2s. per lb., Best Quality	Madagascar, France. India.

Lead	From home ores, 20,000 From imported concentrates, 40,000.	122,000	182,000	40,000	182,000	£18	£30	Australia, U.S.A., Spain, Burmah, Beira.
Nickel	3,976	11,000	14,976	—	14,000	£169	£225	U.S.A.
Matte	—	—	—	10,753	—	—	—	Canada.
Ore	—	—	—	15,000	—	—	—	—
Resin	—	84,000	84,000	—	80,000	£4–£5 American	£65	France, U.S.A., Spain, Portugal.
Spelter	53,415	95,173[3]	148,588	—	116,620	£23 (G.O.B.)	£52	U.S.A., Spain.
Calamines ..	—	—	—	64,000	—	—	—	—
Spelter (G.O.B.)	46,360	62,874[3]	109,234	—	84,882	—	—	—
Spelter (Fine)	7,055	32,299	39,354	—	31,738	—	—	—
Tin and Tin Ore	From home ores, 4,000. From imported ores, 24,000.	26,000	54,000	58,000	22,000	£160	£238	Straits Settlements, Bolivia.
Tungsten ..	3,193[4]	128	3,321	—	3,051	—	—	—
Wolframite ..	147	—	147	8,076	8,076	£1 12s. per 20 lb. unit	£2 15s.	Burmah, Australia, Straits Settlements, Bolivia, &c.

[1] D.M.RS/510.
[2] About one-third of total imports is used in this country, the rest re-shipped to Italy, France, and America.
[3] Of this 13,734 tons were re-exported to Scandinavia.
[4] Of this 131 tons were exported.

APPENDIX III.

Principal Regulations controlling Materials under the Defence of the Realm Acts.[1]

30a. No person shall, without a permit issued under the authority of the Admiralty or Army Council or the Minister of Munitions, either on his own behalf or on behalf of any other person—

(*a*) buy, sell, or deal in ; or

(*b*) offer or invite an offer or propose to buy, sell, or deal in ; or

(*c*) enter into negotiations for the sale or purchase of or other dealing in ; any war material to which this regulation may for the time being be applied by order of the Admiralty or Army Council or the Minister of Munitions, or any right in any invention, design, or process of manufacture relating to any war material, being war material to which this regulation may for the time being be so applied, whether or not the sale, purchase, or dealing is, or is to be, effected in the United Kingdom.

If any person acts in contravention of the foregoing provision, or aids or abets any other person, whether or not such other person is in the United Kingdom, in doing anything which if done in the United Kingdom would be a contravention of the foregoing provision, or fails to comply with any condition subject to which a permit under this regulation has been granted, such person shall be guilty of an offence against these regulations, and if such person is a company, every director and officer of the company shall also be guilty of an offence against these regulations, unless he proves that the contravention took place without his knowledge or consent :

Provided that nothing in this regulation shall affect any transaction authorised by a permit of the competent naval or military authority under Regulation 30.

30b. It shall not be lawful for any person on his own behalf or on behalf of any other person to sell or buy, or to offer to sell or buy,

(*a*) any of the following metals :—iron (including pig-iron), steel of all kinds, copper, zinc, brass, lead, antimony, nickel, tungsten, molybdenum, ferro-alloys ; or

(*b*) any other metal which may be specified in an order of the Admiralty or Army Council or the Minister of Munitions as being a metal required for the production of any war material.

unless in the case of a seller the metal to be sold is in the possession of the seller or is in the course of production for him, or in the case of a buyer the purchase is made for or on behalf of a consumer ; and it shall be lawful for the Admiralty or Army Council or the Minister of Munitions, or any person authorised by them or him for the purpose, to require any person who on his own behalf or on behalf of any other person, has sold or bought, or offered to sell or buy any such metals, to prove that the sale or purchase complies with the requirements of this regulation, and if any such person on being so required fails to produce satisfactory proof that it does so comply he shall be guilty of an offence against these regulations, and if such person is a company every director and officer of the company shall also be guilty of an offence against these regulations :

Provided that it shall be lawful for the Admiralty or Army Council or the Minister of Munitions by order to exclude from the provisions of this regulation any of the metals above mentioned, and whilst any such order remains in force this regulation shall have effect as if such metal were not mentioned therein.

30c. Any person brought before a court of summary jurisdiction charged with having in his possession or under his custody or control any tungsten or tungsten ore or products therefrom, high-speed steel or scrap therefrom, molybdenum, vanadium, cobalt, nickel, or any alloy used in the manufacture of high-speed steel, or any other metal required for the production of war material for the time being specified in an order made for the purpose by the Admiralty or Army Council or the Minister of Munitions, which may be reasonably suspected of being stolen or unlawfully obtained or acquired, who does not give an account to the satisfaction of the court how he came by the same, shall be guilty of a summary offence against these regulations.

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[1] For other Regulations affecting metals see Vol. II, Part I, Chap. VII.

APPENDIX IV.

(CHAPTER X.)

Regulations under the Defence of the Realm Acts relating to Motor Spirit.

15a. Every person who uses or keeps motor spirit, whether for the purpose of supplying motive power to motor cars or for any other purpose, shall supply such information in relation to the motor spirit used or kept by him, and the purposes for which and the manner in which it is used or kept by him, as the Board of Trade may by any general or special order require, giving such particulars in such form and at such times as the Board of Trade may by order direct; and if any person fails to comply with this regulation, or with any order made by the Board of Trade thereunder, or knowingly gives any false information, he shall be guilty of a summary offence against these regulations.

For the purposes of this regulation "motor spirit" has the same meaning as in section eighty four of the Finance (1909-10) Act, 1910.

8g. On and after the first day of September, nineteen hundred and sixteen, motor spirit shall not be used for the purpose of char-a-bancs or other like vehicles on any excursion or trip of any sort except—

(*a*) trips in connection with ambulance or hospital work or the conveyance of wounded soldiers; or

(*b*) trips in connection with naval, military or munition service or the conveyance of munition workers to or from their work; or

(*c*) trips which are certified by the chief officer of police for the police area in which the motor spirit is used to be necessary or desirable in the interests of the travelling public.

If any person uses motor spirit or causes or permits motor spirit to be used in contravention of this regulation, he shall be guilty of a summary offence against these regulations.

In this regulation the expression "motor spirit" has the same meaning as in Part VI. of the Finance (1909-10), Act, 1910.

8gg. On and after the twelfth day of May nineteen hundred and seventeen, motor spirit shall not be used for the pupose of any motor car let for hire except where the letting of the car—

(*a*) is in connection with ambulance or hospital work or the conveyance of wounded soldiers, or is to a duly qualified medical practitioner for the purposes of his profession; or

(*b*) is in connection with naval or military or munition service or the conveyance of munition workers to or from their work; or

(*c*) is authorised by the Board of Trade for any special purpose.

If any person uses motor spirit, or causes or permits motor spirit to be used, in contravention of this regulation, he shall be guilty of a summary offence against these regulations.

In this regulation the expression "motor spirit" has the same meaning as in Part VI. of the Finance (1909-10) Act, 1910.

Nothing in this regulation shall apply to any motor cab or motor omnibus standing or plying for hire in any street or public place or in any railway station; but any question as to whether or not a car is exempt under this provision shall be referred to the Board of Trade, whose decision shall be conclusive.

2aaa. With a view to developing as economically and expeditiously as possible any supply of petroleum which may exist in strata in the United Kingdom it shall be lawful for the Board of Trade or the Minister of Munitions or any person authorised by them or him, but for no other person, to search and bore for and get petroleum, and the Board of Trade or Minister of Munitions or a person so authorised for the purposes aforesaid may enter on or take possession of any land and sink wells and construct other works thereon.

If any person searches or bores for or gets petroleum in contravention of this provision he shall be guilty of a summary offence against these regulations.

For the purposes of this regulation petroleum means all petroleum and its relative hydrocarbons (excluding coal and shales), and natural gas existing in their natural conditions in strata, but does not include natural gas set free in the course of mining or other lawful operations.

APPENDIX V

Schedule of Control Orders relating to Non-Ferrous Materials.

Title of Order.	Date.	Effects.
Aluminium.		
(1) —	7/12/15	Applies Regulation 30A to all kinds of aluminium and alumina.
(2) —	21/7/16	Specifies classes of aluminium to which Regulation 30A applies; cancels (1).
(3) Aluminium Order, 1916	2/12/16	Includes scrap and swarf under Regulation 30A; cancels (2).
(4) Aluminium (Returns) Order, 1917.	17/2/17	Requires returns.
(5) Aluminium (Scrap and Swarf) Order, 1917.	28/2/17	Controls use, sale, and method of production of scrap and swarf; requires returns; fixes maximum prices.
Antimony.		
—	29/2/16	*See* Regulation 30B.
Bismuth.		
Bismuth Order, 1918	12/3/18	Applies Regulation 30A; requires returns.
Brass.		
(1) —	29/2/16	*See* Regulation 30B.
(2) Brass and Copper (Returns) Order, 1916	1/12/16	Requires returns of brass rod, &c.
(3) Brass (Swarf and Scrap) Control Order, 1917.	24/2/17	Takes possession of scrap and swarf, requires returns.
Chrome Ore.		
Chrome Ore Order, 1917	31/8/17	Subjects dealings to licence.
Cobalt.		
—	12/4/16	*See* Regulation 30C.
Copper.		
(1) —	29/2/16	*See* Regulation 30B.
(2) Copper, Zinc, and Tin (Unauthorised Possession) Order, 1916.	5/6/16	Applies Regulation 30C.
(3) —	6/11/16	Prohibits manufacture of copper wire or cable except for Government contracts.
(4) Brass and Copper (Returns) Order, 1916	1/12/16	Requires returns of copper rod, wire, &c.
(5) Copper (Use in Manufacture) Order, 1916	8/12/16	Prohibits use except for certain Government contracts; cancels (3).
(6) Copper (Sale or Purchase) Order, 1916.	8/12/16	Subjects to licence dealings in copper; requires returns of unwrought copper.
(7) Copper(Control) Order, 1917.	1/1/17	Takes possession of unwrought copper; requires returns from smelters and refiners.

APPENDIX V—*contd.*

Title of Order.	Date.	Effects.
Cupro-Nickel Scrap.		
Cupro-Nickel Scrap (Dealings) Order, 1917.	9/3/17	Subjects dealing to licence; requires returns.
Lead.		
(1) —	29/2/16	*See* Regulation 30B.
(2) —	2/2/17	Prohibits dealings without a licence in pig lead situated outside U.K.; subjects to licence, with certain exceptions, dealings in, and use of pig lead in U.K.; requires returns.
(3) —	6/4/17	Amplifies provisions of (2) and applies them to lead and lead compounds of all kinds; fixes maximum prices; cancels (2).
(4) Lead Order, 1917 ..	1/9/17	Takes possession of pig and scrap lead; amplifies provisions of and cancels (3).
(5) Lead Control (Amendment) Order, 1918.	19/2/18	Fixes maximum prices for type metal.
(6) Type Metal (Returns) Order, 1918.	28/5/18	Requires returns of type metal.
(7) Lead (Amendment) Order, 1918.	28/6/18	Revises maximum prices.
Mica.		
Mica Control Order, 1918.	15/ 4/18	Subjects to licence dealings in and use of mica; requires returns.
Mineral Oils.[1]		
(1) [Creosote, &c.] ..	13/7/17	Subjects to licence use for treating wood, &c., of creosote and other oils produced from distillation of coal tar; subjects dealings to licence.
(2) [Creosote, &c.] ..	13/7/17	Requires returns from consumers of creosote and other oils with a specific gravity of 1·000 or more.
(3) Benzol and Naphtha Order, 1917.	29/8/17	Subjects dealings to licence; requires returns.
(4) Coal Tar Order, 1917	4/9/17	Subjects to licence dealings in quantities above 10 gallons, except purchases for distillation.
(5) Tar Oils Order, 1917	23/10/17	Takes possession of tar oil fractions suitable for fuel; subjects to licence dealings in and use of any tar oil; fixes maximum prices; requires returns; cancels (1).

[1] For the orders relating to motor spirit, &c., issued by the Board of Trade *see* pp. 140, 141 in the text.

APPENDIX V—*contd.*

Title of Order.	Date.	Effects.
(6) Tar (Coal and Water Gas) Order, 1917.	31/12/17	Extends terms of (4) to water-gas tar; prohibits use of tar for certain purposes; subjects to licence use for other purposes; cancels (4).
(7) Solvent Naphtha Order, 1917.	31/12/17	Subjects dealings to licence; requires returns.
(8) Tar Oils Control Order, 1918.	1/2/18	Amplifies provisions of (5) and applies them to additional classes of oil; revises maximum prices; cancels (5).
Nickel.		
(1) —	29/2/16	*See* Regulation 30B.
(2) —	12/4/16	*See* Regulation 30C.
Oxygen.		
Oxygen Order, 1917[1]	17/12/17	Subjects sales to directions from Admiralty; requires returns.
Platinum.		
(1) Platinum Order, 1915.	31/12/15	Applies Regulation 30A to platinum metal, ores, &c.
(2) Platinum Metal Order, 1916.	31/5/16	Confirms inclusion of platinum metal in (1).
Rosin.		
Rosin Control Order, 1918.	31/1/18	Subjects to licence dealings in rosin and rosin oil; requires returns.
Shellac.		
Shellac Control Order, 1918.	12/3/18	Requires returns; subjects dealings to licence.
Spelter.		
(1) Spelter (Control) Order, 1917.	23/3/17	Subjects to licence dealings in and use of spelter and zinc; requires returns.
(2) Spelter Control (Amendment) Order, 1918. *See also* Zinc.	22/1/18	Extends application of (1).
Tin.		
(1) Copper, Zinc, Tin (Unauthorised Possession) Order, 1916.	5/6/16	Applies Regulation 30C.
(2) Tin (Dealings) Order, 1917.	21/12/17	Applies Regulation 30B.
(3) Tin (Dealings) Order, 1918.	26/4/18	Subjects to licence dealings in and use of, tin; requires returns.
Zinc.		
(1) —	29/2/16	*See* Regulation 30B.
(2) Copper, Zinc, Tin (Unauthorised Possession) Order, 1916. *See also* Spelter.	5/6/16	Applies Regulation 30C.

[1] Order made by the Admiralty.

APPENDIX VI.

(CHAPTER II., p. 20.)

Output of Copper Bands.

(*a*) OUTPUT BY THE DIFFERENT METHODS.

Size.	From Solid Drawn Tube.	Brazed.	Cast.	Butt-Jointed.	Pressed out of Plate.	Total.
14 in.–18 in. ..	111,000	—	5,000	—	—	116,000
12 in. and under 14 in.	457,000	—	2,000	—	17,000	476,000
9 „ „ „ 10 „	1,100,000	—	176,000	—	1,426,000	2,702,000
6 „ „ „ 8 „	6,336,000	—	46,000	5,960,000	12,972,000	25,314,000
5 in.	5,957,000	—	—	1,304,000	7,634,000	14,895,000
4·5 in. and under 5 in.	9,269,000	418,000	—	4,005,000	10,783,000	24,475,000
3·5 „ „ „ 4·5 „	2,331,000	—	—	—	24,000	2,355,000
3 „ „ „ 3·5 „	55,535,000	3,874,000	—	17,236,000	13,943,000	90,588,000
Under 3 in.	9,910,000	—	—	—	2,466,000	12,376,000
	91,006,000	4,292,000	229,000	28,505,000	49,265,000	173,297,000
Number of Contractors	39	13	6	15	41	114

(*b*) THE PRINCIPAL SUPPLIERS.

Direct—

The Broughton Copper Company, Ltd.	28,901,000
Messrs. T. Bolton & Sons	17,791,000
The Yorkshire Copper Works, Ltd.	16,020,000

Cutters up—

Messrs. Lindsay & Company	4,352,000
Messrs. G. Tucker & Company	1,958,000

Brazed—

Master Silversmiths' Association	2,890,000
Messrs. Fenton Brothers	756,000

Butt-Jointed—

Master Silversmiths' Association	6,800,000
Messrs. T. Bolton & Sons	4,552,000
Messrs. F. Braby & Company	5,800,000
Messrs. G. Tucker & Company	1,470,000
Messrs. Daniel & Arter	2,657,000

Rings Pressed Out of Plate—

Messrs. T. F. Braime & Company	7,933,000
The Birmingham National Shell Factory	8,882,000

APPENDIX VII.

(CHAPTER VII., p. 108.)

Agreement for Establishing an Inter-Allied Tin Executive in London.

In order to provide for controlling the procurement and distribution of tin to meet the requirements of the countries participating in this agreement it is agreed as follows :—

1. That an Inter-Allied Tin Executive be established in London, composed of one or more representatives of each country participating, with authority to carry out the arrangements agreed upon by the appropriate Governmental Agencies in each country.

These arrangements shall be modified and readjusted from time to time by such further agreements as may be required in order to serve the best interests of all concerned.

2. The present arrangements, subject to modification and readjustment as above provided for, are :—

(i) The allocation of pig tin to the countries participating shall be on the basis of the following estimated minimum annual requirements—

For the United States	80,000	gross tons
For Great Britain	25,000	,, ,,
For France	13,000	,, ,,
For Italy	4,500	,, ,,

(ii) As part of the United States allotment 60 per cent. of the Straits tin output shall, during the continuance of this arrangement, be allocated to the United States.

(iii) During the continuance of this arrangement Great Britain will refrain from purchasing tin from China (except Hong-Kong), Mexico, the Dutch East Indies, Central America, South America, or Australia, or more than 30 per cent. of the Hong Kong output. Great Britain and the United States shall both be at liberty to purchase ore and concentrates in South America in such proportions as may be required to enable, so far as possible, the smelters in both Great Britain and the United States to operate to their full capacity.

(iv) The French and Italian requirements will be supplied through Great Britain from its allocation of Straits tin and the output of smelters in Great Britain. During the continuance of this agreement these countries will refrain from purchasing or procuring tin otherwise than as above specified on the understanding that their requirements will be fully supplied up to the amounts allocated to them.

(v) In case the total available annual supply of pig tin from all sources is found to be insufficient to provide the participating countries with the amounts allocated to them as above, it is agreed that the respective allotments of the participating countries shall be reduced proportionately and their respective shares readjusted on that basis.

(vi) All purchases for the countries represented on the Executive exclusive of those already contracted for, shall be made under the direction of the Executive. The Executive may appoint a Director of Purchases in London, and buying agencies in any or each of the various producing centres—these agencies to be the sole channel through which the various participating countries are to purchase the quantities of tin allocated to them in accordance with this agreement.

(vii) As to tin produced in one of the participating countries and forming part of the allocation of another, the purchasing agency of the latter country will be permitted to procure its allotted share at the same price at the place of production as that paid by the producing country for its share. If necessary for this purpose, all purchases for account of both countries will be pooled as to price at the place of production and the share of each paid for at the pool price.

(viii) The Executive may, from time to time, fix the maximum and/or minimum prices to be paid by the participating countries for pig tin or tin ore in any producing country, with the view, on the one hand, of preventing price raising by competitive buying, and on the other of stimulating production by increasing the profits of the producers.

(ix) In case the allocation of markets results in disadvantage to any of the participating countries through inequality of prices in the various markets, the cost of purchases in the different markets may be equalised by monthly readjustments so that all participating countries will pay the same average price for their respective shares. The Executive may require all purchases made for account of more than one of the participating countries in a common market to be pooled as to quantity and price.

(x) Each of the countries represented on the Executive shall keep the Executive fully informed of all purchases of tin from all sources for its own use.

(xi) The Executive will collect information as to the measures adopted in the participating countries for economy in the distribution and use of tin, and may, whenever it is considered desirable, make recommendations to this end to any or all of the participating countries.

Dated in London this 28th Day of August One Thousand Nine Hundred and Eighteen.

For the Ministry of Munitions of War.

LEONARD W. LLEWELYN.

Controller Non-Ferrous Materials Supply.
For the United States of America War Industries Board.

LELAND W. SUMMERS.

Pour le Ministère de l'armement et des fabrications de guerre 2 September 1918.

SAUVAGE.

Chef de la Division Electro-Metallurgique.
For the Italian Ministry of Munitions.

COLONEL RIGGI

2 September, 1918.

APPENDIX VIII.

(CHAPTER VIII., p. 114.)

Inter-Allied Agreement for Platinum Control.

At a meeting of Sub-Committee B of the Inter-Allied Non-Ferrous Materials Committee, held on October 9th, 1918, it was unanimously agreed that the adoption of some plan for the control and distribution of platinum and platinum metals was imperative.

It was further agreed that two members of the Committee should be appointed who should, with the Secretary, form a Sub-Committee to formulate such a plan, and that, in order to save time, this Sub-Committee should report direct to the main Committee on Non-Ferrous Materials.

Colonel A. L. Foster and Mr. Lincoln Hutchinson were appointed members of this Sub-Committee.

This Sub-Committee now begs to report to the Committee on Non-Ferrous Materials recommendations as follows :

That the Governments of Great Britain, France, Italy, and the United States be requested, through the proper channels, to enter into an agreement to form an Inter-Allied Platinum Executive, this agreement to be substantially in the following form :—

AGREEMENT.

In order to provide for controlling the procurement and distribution of Platinum to meet the requirements of the countries participating in this Agreement it is agreed as follows :—

1. That an Inter-Allied Platinum Executive be established in London, composed of one or more representatives of each country participating, with authority to carry out the arrangements agreed upon by the appropriate Governmental Agencies in each country.

These arrangements shall be modified and readjusted from time to time by such further Agreements as may be required in order to serve the best interests of all concerned.

2. The present arrangements, subject to modification and readjustment as above provided for, are :—

(i) The term " Platinum " shall be understood to include all the Platinum metals, namely : Platinum, Iridium, Rhodium, Osmium, and Ruthenium.

(ii) All purchases of Platinum shall be for joint account of all the countries participating in this Agreement, and their respective shares shall be allocated to them in direct proportion to their war requirements as determined by the Inter-Allied Munitions Council :

Provided, however—

(*a*) That pending determination by the Inter-Allied Munitions Council of the war requirements of the participating countries, certain purchases reported to be at present under negotiation in Sweden by the Governments of Great Britain and the United States may be completed, and that, if completed before the war requirements of the various countries shall have been determined by the Inter-Allied Munitions Council, any quantity secured up to 25 poods shall be divided equally between Great Britain and the United States, the excess, if any, between 25 and 40 poods to be taken by the United States : and

(*b*) that as to certain other purchases in Siberia reported to be under negotiation by French and American interests, any quantities purchased before the determination by the Inter-Allied Munitions

Council of the war requirements of the various participating countries shall be divided equally between Britain, France, and the United States ; and

(*c*) that as regards all such lots purchased as above in Sweden and Siberia, each country will pay for its quota at the point of delivery in the currency required, unless, in the judgment of the Platinum Executive, the circumstances in any particular case are such as to make other methods of payment desirable.

3. All purchases of Platinum for the countries represented on the Executive, except those provided for in (II) (*a*) and (II) (*b*) above, shall be made under the direction of the Executive. The Executive may appoint a Director of Purchases in London and Buying Agencies in any or each of the producing centres, these Agencies to be the sole channel through which the various participating countries are to purchase the quantities of Platinum allocated to them in accordance with this Agreement.

4. As to Platinum produced in one of the participating countries and forming part of the allocation of another, the producing country will purchase the Platinum for account of the country to which it is allocated, and deliver to the latter at the price actually paid for the Platinum plus cost of delivery.

5. The Executive may from time to time fix the maximum and/or minimum prices to be paid by the participating countries for Platinum in any producing country, with the view, on the one hand, of preventing price-raising by competitive buying, and, on the other, of stimulating production by increasing the profits of the producers.

6. The Executive may from time to time recommend the fixing of the selling prices of Platinum Metal in the various countries party to this Agreement in order that they may be kept approximately equivalent.

7. The Executive may require all purchases made for account of more than one of the participating countries in any market to be pooled as to quantity and price.

8. Each of the countries represented on the Executive shall keep the Executive fully informed of all purchases of Platinum from all sources for its own use.

9. The Executive will collect information as to the measures adopted in the participating countries for economy in the distribution and use of Platinum, and may, whenever it is considered desirable, make recommendations to this end to any or all of the participating countries.

10. This Agreement is for the period of the War.

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HISTORY OF THE MINISTRY OF MUNITIONS.

VOLUME VII

THE CONTROL OF MATERIALS.

PART IV

MATERIALS FOR EXPLOSIVES MANUFACTURE

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VOLUME VII

THE CONTROL OF MATERIALS

PART IV

MATERIALS FOR EXPLOSIVES MANUFACTURE

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CHAPTER I.

INTRODUCTION.

Nearly all the explosives which were used for the purposes of the war were nitrated products requiring for their manufacture large quantities of acids, chiefly nitric acid to effect nitration and also sulphuric acid, which was needed for absorbing the moisture given off during that process and for the manufacture of nitric acid itself. The high explosives were mainly nitrated coal-tar products based upon toluol, phenol or ammonia. The propulsive explosives consisted of some form of nitrocellulose, cotton-waste being the material used, intimately mixed with nitrated glycerine. The solvents used in making propulsive explosives were acetone and ether-alcohol.

I. Development of State Control over Explosives Materials.

The interest of the State in maintaining an adequate supply of these materials brought it into intimate relations with many industries of a very diverse nature. The policy adopted depended very largely upon the changing circumstances of the time, and differed with the natures of the industries affected. Direct control began with the acquisition of the country's entire output of toluol in December, 1914. With explosive, as with other materials, the stringent tonnage position of the last two years of warfare led to a much higher degree of State control than was assumed during the years 1914–16.

At the outbreak of war, the Government had a direct interest in the supply of explosives materials for the Royal Gunpowder Factory only ; but a national reserve had been accumulated of two products, viz., acetone and oleum, for which the country depended almost entirely upon overseas supplies. Stocks of these had been maintained chiefly on behalf of the navy. During the early years of the war, it continued to be the practice to accumulate, against an emergency, reserves of certain imported materials, such as pyrites and sodium nitrate, which for the time being were plentiful. Action was taken in August and September, 1914, to prohibit the exportation of materials essential to explosives manufacture. Reliance was placed upon the moral effect of the powers taken in August, 1914, for requisitioning stocks under the Army (Supply of Food, Forage and Stores) Act, to restrict advances in the price of natural phenol. It was not until the demand for large quantities of a new explosive, T.N.T., arose in the following October that any direct action was taken to requisition materials for explosives supply or to supply explosives makers with them.

The few existing makers of T.N.T. then alleged that speculators were holding up toluol. It was, moreover, necessary to ensure a supply of the materials, toluol and oleum, for the new enterprises which were undertaking to make T.N.T. The Contracts Department of the War Office received, as a result of widespread tenders for toluol, a few offers representing less than a month's supply. It was thought that the War Office should take immediate control of the country's output of this material. In order to cope with the technical and industrial difficulties involved in the supply of materials for explosives, Lord Moulton's Committee on the Supply of High Explosives was appointed on 13 November, 1914, to investigate particularly the question of raw materials.[1] At first, the Committee preferred to bargain with individual benzol distillers as to the recovery of toluol; but power to requisition the output, as well as the stocks, of toluol was taken at their recommendation by a clause inserted in committee in the Defence of the Realm (Consolidation) Act on 23 November, 1914.[2]

The general policy of the Committee was to interfere as little as possible with the industries concerned in producing coal-tar derivatives. All coal-tar producers were notified early in December, 1914, that the whole of their output of toluol or substances containing toluol should be placed at the disposal of the Army Council for the period of the war, but that existing contracts would be interfered with as little as possible, and that no control would be taken over products containing less than 3 per cent. of toluol. Dealings in tar were then left uncontrolled; but all tar distillers and coke-oven and gas undertakings distilling their own tar were required to make returns concerning their output, and their dealings were all subject to permits issued by the Committee. Practically the whole of the country's output was then purchased for the manufacture of T.N.T., a very small proportion only being allocated to the essential needs of the dye industry.

Picric acid makers were dependent upon the raw material phenol, the prices for which advanced rapidly immediately after the outbreak of war. It was at first considered unnecessary to requisition this material, since export was prohibited, and the manufacture of explosives was practically the only outlet for it. By April, 1915, the market had steadied, and the opportunity was used to take over all phenol contracts from the picric acid makers. Agreements were made for practically the whole of the country's output of natural phenol, permits for dealings for other purposes being restricted to medical requirements. In the summer of 1915 this method of purchasing the whole of the country's output by agreement, already applied to toluol and natural phenol, was again used with a view to securing commercial benzol for the manufacture of synthetic phenol. Nearly all the producers of commercial benzol agreed voluntarily to place their output at the disposal of the State, and it was only necessary to

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[1] See Vol. X., Part IV., p. 22. [2] Hist. Rec./H/1520/11.

enforce the powers of requisitioning output, which had been taken in the previous November, in the case of the few remaining benzol producers.

Ether alcohol was introduced as an alternative solvent to acetone, of which supplies were short, in the autumn of 1915. In the following May, Defence of the Realm Regulation 30D was promulgated in order to secure adequate supplies of alcohol and to prevent the undue consumption of grain in the manufacture of potable spirits. This regulation subjected the use of grain for distillation to permits to be issued by the Propellants Branch of the Ministry of Munitions. In effect, it brought all the distilleries of the United Kingdom under the virtual control of the Ministry throughout the war. Similarly, the dependence of cordite production upon glycerine supplies brought the Ministry into intimate relations with the soap and candle industries, of which glycerine is a by-product. In August, 1915, it became apparent that the available supplies of glycerine would be inadequate to meet the new gun ammunition programmes. The whole of the stock and output was accordingly requisitioned at a fixed price, which was considerably less than half the lowest rates in free markets during the remainder of the war. The sale of glycerine for industrial purposes was restricted gradually, at first by means of permits to makers, and later by a more stringent system of licensing consumers.

Until the autumn of 1915 there had been little difficulty in regard to supplies of acids, since the general dislocation of industry had set free considerable quantities normally used for various manufactures. The enormous extension of explosive production to meet the new gun ammunition programmes of 1915 gave rise to a campaign of acid economy, which the Explosives Supply Department carried out during the winter of 1915–16 among makers of explosives and of other products, such as fertilisers. In February, 1916, acid makers' works were declared controlled establishments, and an informal regulation of the acid trade began. Thus, in February, 1916, without assuming the necessary legal powers, the Ministry fixed acid prices and began to receive from sulphuric acid makers regular returns relating to their output. Similar returns were received from nitric acid makers from the following July onwards.

In October, 1916, power was formally taken to demand returns relating to methods of work, cost of manufacture, dealings and prices from all makers of coal-tar or coke-oven by-products, including ammoniacal liquors and sulphate of ammonia, the supply of which was then becoming a matter of importance in view of growing demands for ammonium nitrate. The growing stringency of the shipping position affected the Department's policy in regard to explosives materials from the winter of 1916–17 onwards. Moreover, by this date, responsibility had been assumed for supplying explosive makers with the greater part of their raw materials. The acquisition of the whole of the country's output of coal-tar products in 1914–15 had

rendered the Ministry responsible for providing the basic material for high explosives. Towards the close of 1916 the provision of the main materials for cordite production was undertaken as a means of freeing prices from undue inflation on this score. All explosive makers had been encouraged to instal their own acid plant, and in December, 1916, the Ministry undertook to purchase and distribute one of the main raw materials, sulphur, of which a world shortage was threatening. The purchase and distribution of all imported pyrites was undertaken by the Ministry in July, 1917, and in the following October, dealings in sodium nitrate, the remaining raw material for acid production, were controlled under Defence of the Realm Regulation 30A. The need for minimising shipments of acid materials led to the formal control of the acid industry, which was effected by bringing sulphuric acid under Defence of the Realm Regulation 30A in May, 1917. No formal control was taken over dealings in nitric and hydrochloric acid since the manufacture of these was itself dependent upon the sulphuric acid.

Shipping difficulties, also, together with the demands of the navy for oil-fuel, made it essential to regulate the consumption of all classes of tar-oils, particularly benzol. Supplies of commercial benzol only had been acquired in the summer of 1915. In order to prevent any possible leakage of toluol, and to provide fuel for the navy, the control of the Ministry over dealings in all forms of benzol, naphtha and tar-oils, was gradually completed by a series of orders issued between August, 1917, and February, 1918.

The gradual exhaustion of emergency reserves during the year 1917 gave rise to grave fears of an ultimate shortage of glycerine, while the growing difficulty in importing sufficient foodstuffs placed it in direct rivalry with margarine for the allocation of oils and fats. The consumption of glycerine for non-essential purposes had already been eliminated, and the only further means of controlling consumption were found in reducing the amount of glycerine used per ton of explosive, and by an active intervention in the soap industry to improve the yield of glycerine per ton of fat. The supply of alcohol for munition purposes came into similar conflict with the country's food requirements ; and the need for maintaining yeast manufacture was the main reason for continuing a consumption of grain for this purpose. In these and other instances, efforts were made to reduce the tonnage required by purchasing from abroad the finished product rather than the more bulky raw material. The general tightening up of control, and the reduction of the gun ammunition programme, due also to restricted tonnage, eased the position in regard to the explosives materials during the year 1918. Action taken in controlling industry during that year related mainly to trades in which the Ministry's interest was somewhat indirect. Thus, for instance, the general control of the fertiliser industry had been transferred to the Ministry in February, 1917, owing to the Department's double interest in supplies of acids on the one hand, and of ammonia and ammonium sulphate on the other ; and in April, 1918, an order was issued fixing the prices of

ammonium sulphate and other chemical manures, with the sole object of equalising fertiliser prices generally. Under a subsequent order (May, 1918), the use of ammoniacal products was restricted severely to agricultural purposes, and to the manufacture of ammonium nitrate for explosives. In some cases, the fluctuation in the munitions programme left the Ministry during the closing months of the war in control of the consumption of a material for which the demand for munitions purposes had practically ceased to exist. Thus, restrictions were originally imposed upon the acetic acid industry in the winter of 1917 in order to obtain sufficient supplies for dope and poison gas manufacture without encroaching upon the production of acetone as a cordite solvent. In the spring of 1918 the Ministry's interest in the supply of acetic acid was considerably reduced, but the Department continued to regulate a fair distribution among various industrial consumers of a product for which the trade demand still exceeded supply.

II. Sources of Supply.

In one respect the position of Great Britain was very favourable for explosive manufacture, since her great coalfields provided immense quantities of tar products. Advantage was taken of this fact, not only to provide the British forces with explosives, but to issue essential materials to the Allies. Thus, the total quantity of benzol delivered to the French Government, whose coalfields were in the enemy's hands, exceeded 103,000 tons. The country's output of toluol and phenol was restricted for the most part by the amount of recovery and refining plant which was available or could be erected. During the year 1915 it was found necessary to supplement this capacity by establishing plant for deriving toluol from imported petroleum.

In almost every other case the bulk of the raw material was imported from abroad. Acid manufacture depended upon supplies of sulphur from Sicily, pyrites from Spain, and sodium nitrate from Chile. Glycerine, a by-product of the soap industry, was dependent upon imported oils and fats. The cellulose used for cordite production was cotton-waste. The solvent acetone, obtained generally from wood distillation, was imported from America; the solvent alcohol was manufactured chiefly from imported grain. During the first two years of the war comparatively little difficulty was experienced in importing sufficient quantities of these raw materials, and it was even possible to build up certain reserves against emergencies. The chief problems between 1914 and 1916 were to establish suitable plant for treating the indigenous and imported products, and to purchase them at reasonable prices in face of an increasing and world-wide demand. It was during this period, for example, that acid plants were erected at National Explosives Factories, on an unprecedented scale, and that distillers were induced to manufacture the largest possible quantities of alcohol for munitions purposes. In the more delicate markets, such as the American acetone market, the con-

centration of all British purchases in the hands of the State facilitated economical buying. Perhaps the most remarkable effort to ensure a cheap supply was the fixing of glycerine prices in the autumn of 1915.[1]

The grave effect of so large a dependence upon overseas materials began to show itself with the gradual restriction of tonnage in 1916, and grew in seriousness with the development of the unrestricted submarine campaign and the increasing difficulties of the American exchange. A very great part of the material used for explosives was derived from products which were also utilised for the supply of food. Even acid supply was indirectly affected by the primary importance of food production and the earlier policy of diverting sulphuric acid from the fertiliser industry to explosives manufacture was reversed early in 1917. Oils and fats, the basic materials of the soap and glycerine industry, were also essential to margarine production. With the initiation of the Food Controller's schemes for making butter substitutes, soap-making was restricted by a limited ration of oils and fats instead of being encouraged to the utmost as a source of glycerine production. Similarly, the distilleries which did not produce yeast for bread-making were entirely closed in the spring of 1917, and the impracticability of introducing a substitute leaven was one of the main reasons for continuing the consumption of grain in the manufacture of spirit. Restriction of this and other industries (*e.g.*, soap manufacture) beyond a certain limit was, however, considered impolitic, in view of their important export trade and the financial interests involved.

During these times of stringency various schemes were set on foot for exploiting home resources; but in several instances the extreme urgency had passed before the plans had had time to mature. Thus, none of the three new wood-distillation factories projected late in 1917 was complete at the date of the Armistice. Similarly, a project for obtaining nitrogen products from the atmosphere was delayed by technical and practical difficulties and by the general shortage of plant, labour and money until it was finally relegated to future completion as a peace-time measure. Nevertheless, very great improvements were made throughout the war in British methods of producing explosive materials.

III. Improvements in Method and Practice.

The technical advances made in this direction were so great that it would be impracticable to attempt any exhaustive description of them here. One of the most notable processes introduced was the distillation of toluol from Borneo petroleum upon plant which was brought from Holland in January, 1915, erected at Government expense and operated as an agency factory. British firms had always made picric acid from natural phenol, although the production of synthetic phenol was well known in France. In the spring of 1915 the synthetic manufacture of phenol from benzol was undertaken by several British

[1] See below p. 79.

chemical and explosives makers, the necessary plant being installed at Government expense. Two novel methods of obtaining toluene from gas were introduced into the works of over 600 gas undertakings, and very satisfactory output was obtained under advice from the Explosive Supply Department's inspectors and district engineers. Except for the one process adopted at the larger gas works, special plant was not needed for this purpose. The companies entered upon the scheme voluntarily, but the Department undertook at first to provide sufficient enricheners to maintain the statutory quality of the gas, and afterwards enforced the adoption of the process under the Defence of the Realm Act in order to protect the companies. The distillation of acetone from wood was extremely limited in Great Britain until the small existing factory already established by the Department of Woods and Forests was expanded in 1915, and other national projects were set on foot for recovering the products of wood distillation. An entirely new process for deriving acetone from maize was also adopted in certain distilleries suited for the purpose in the spring of 1916, but was subsequently abandoned in view of the shipping position.

A considerable amount of active intervention was also exercised by supply officers in order to ensure good works practice and the largest possible yield of essential materials. A very close control over acid production was established for this purpose during the winter of 1915-16, and formed part of the general system for promoting efficiency in explosive factories which is described elsewhere.[1] In certain contracts, as for example, the orders placed for concentrated ammonia liquor in 1916, it was uniformly stipulated that the gas works concerned should be open to Government inspection in order to ensure efficiency. Again, the need for ensuring the largest possible yield of glycerine from the limited quantities of oil and fat which were available led to a direct intervention in the methods of soap production in 1918. Such methods were greatly facilitated by the fact that the provision of necessary raw materials had become the responsibility of the State.

IV. Rationing the Explosive and Other Industries.

In the winter of 1914, when the State became the sole supplier of coal-tar products to explosive makers, a corresponding control was obtained over their consumption of these materials. The methods used for obtaining from contractors the largest possible yield out of the materials available have been described elsewhere.[2] Occasionally, special prices were charged to contractors for materials used in excess of a standard based upon the practice at the national factories. The control over consumption at explosive works was extended gradually and was completed by revised forms of contracts for 1917, under which the Department became entirely responsible for the supply of raw materials to explosives manufacturers at certain fixed rates.

The rationing of non-munition industries was a more complex problem. On the whole, it was effected by means of a system of permits

[1] Vol. X., Part IV., p. 81–84. [2] Vol. X., Part IV., Chap. V., VII.

to sell. As the position in regard to each material became more stringent, the issue of these permits was restricted to the most essential purposes. Thus, the issue of new spirit for gin-making was stopped in April, 1917, and in the following month the supply of new spirit for any industrial purpose except the manufacture of medical preparations was prohibited. In the case of glycerine, the control by means of permits to sell was subsequently strengthened by means of a system of permits to consumers or to agents for sale, such as pharmacists. In this way, consumption was limited to one or two essential industries. The rationing of acetic acid presented a particularly difficult problem by reason of the numerous small industries involved and the existence of large numbers of merchants. Distribution to the numerous small consumers was continued through these agents for the sake of convenience, but with larger consumers of acetic acid, as well as with industries consuming other explosive materials, direct relations were maintained with a view to simplicity and completeness of control. A very notable feature in the rationing of sulphuric acid was the enforced use of substitutes. Thus nitre-cake was gradually introduced in place of sulphuric acid for grease recovery and many other purposes. The issues of nitre-cake were at first made free from the national factories, which would otherwise have been obliged to pay for its disposal as waste. The substitution of nitre-cake for acid was then a voluntary act upon the part of the various industries which accepted it. With the growing stringency of the shipping position, and the consequent limitation of materials for sulphuric acid manufacture, it became possible to charge a gradually increasing price for nitre-cake. After formal power to restrict dealings in sulphuric acid was taken in May, 1917, the use of nitre-cake was forced upon certain industries by means of withholding the alternative acid.

V. Prices.

The first orders for explosives were placed on the ordinary tender system of the War Department, but sliding scale contracts based on the cost of raw materials gradually became general, until, towards the end of 1916, the Explosives Supply Department undertook to issue the main materials to cordite makers for 1917 at flat rates, and during the summer of 1917 a revision of high explosives contracts enabled the department to make a similar arrangement for these. Flat rates had already been introduced for those materials, such as toluol, phenol and benzol, of which the department had acquired the whole supply, as well as for acetone, which the cordite makers had agreed not to buy so that the overseas market might be free from their competition. The charge made was usually based on cost of production or purchase with a charge of 6 per cent. to cover departmental expenses. The same rates were charged for issues to the Admiralty, but an additional 5 per cent. was added to the price for materials delivered to the Allies to cover part of the expenditure incurred by the Committee on High Explosives.[1]

[1] HIST. REC./H/1500/4.

The assessment of a just rate for explosives materials presented certain peculiar difficulties. Forecasts of the cost of production were hampered by lack of data as to new processes and as to the residual value of novel plant. It was not considered likely that a large proportion of the plant specially erected would have any post-war use.[1] Accordingly, in estimating the cost of production, it became the custom to allow for the amortisation over a single year of 75 per cent. of the original outlay upon plant.

Several methods were adopted to safeguard the department against exploitation, since many of the materials issued could be used for other purposes than the manufacture of explosives. As soon as experience of economic manufacture had been gained in the national factories, a ratio of use of materials was fixed in explosive contracts, and this arrangement was applied to any particular material which it was to the department's interest to supply to contractors.[2]

The fixing of a general scale of prices for materials which should be applicable to all trades was adopted in the case of sulphuric acid, fertilisers and tar oils. In February, 1916, sulphuric acid prices were becoming unduly inflated. Acid works were accordingly scheduled as controlled establishments under the Munitions of War Act. Informal circulars were issued fixing maximum prices during 1916, and on 29 May, 1917, a formal order was issued under the Defence of the Realm Regulations fixing the maximum prices of all sulphuric acid except exported or imported acid or acid made from brimstone or specially purified for laboratory purposes. The schedule of prices was twice revised to meet changes in economic conditions. This method prevented the numerous outside trades which used sulphuric acid from competing with the department for supplies, and it facilitated accounting by the establishment of standardised contracts. It had, however, certain disadvantages. The scale of charges was necessarily high enough to allow small manufacturers a reasonable profit and thus unduly inflated the profit of larger makers. It was also calculated to cover the highest allowances sanctioned for plant construction or repair, and the contractor thus benefited by the use of any surplus payment for this purpose until the over-payment could be recovered as excess profit. Finally, if the charges were fixed too high, contractors outside the explosives trades were apt to make a loss in the execution of their running contracts.[3]

The fixing of prices for fertilisers was primarily intended to benefit agriculture. The first step had been taken by the fixing of ammonium sulphate prices before control of the industry rested with the Ministry of Munitions. In this case the rates were agreed between the Food Production Department of the Board of Agriculture and the Sulphate of Ammonia Association in June, 1917. At the same time, the importation of phosphate rock for the manufacture of superphosphate was undertaken by the Ministry. The scheme, as laid down by the Government, provided for the sale of superphosphate to farmers at fixed

[1] HIST. REC./H/1500/4 ; X. 235/127. [2] HIST. REC./H/1500/4. [3] *Ibid.*

prices in order to encourage food production. The price originally projected was, however, raised by £1 per ton in order to allow for the cost of the imported phosphate, for the cost of superphosphate manufacture, as deduced from an examination of makers' books, and for a reasonable profit, which was reckoned as 10s. per ton of superphosphate.[1] The maximum prices for superphosphate were eventually fixed by an order dated 20 August, 1917. The fixing of prices of compound fertilisers followed in October, 1917, as a natural consequence of the standardisation of rates for ammonium sulphate and superphosphate. Regulation of the prices of tar oils began in October, 1917, and was intended as a means of obtaining economical supplies of fuel for the navy.

In the first instance, the prices paid for toluol and phenol, of which the entire output was purchased in the winter of 1914-15, were settled on a generous basis in order to encourage output, then the main consideration. The rates at which the country's benzol output was purchased were the subject of negotiation during the spring of 1915. The prices arranged in the different benzol areas varied slightly with local conditions. The price was first settled with the larger firms and most of the smaller firms were afterwards induced to supply benzol at the same rates. After undertaking, in April, 1915, to provide British cordite makers with acetone, the War Department was only able to obtain the necessary quantities at a considerable advance in price. It was, accordingly, arranged to refund to explosive makers the difference between the new price and the rates at which they had already placed their orders, so that the price for cordite should remain undisturbed. In this instance, the British supply authorities were hampered by dependence upon a foreign market almost entirely controlled by a single combination. In dealing with glycerine, the position was far more favourable. British control over the whale fisheries and the existence of considerable sources of vegetable oils within the Empire enabled the raw materials for glycerine production to be supplied in large quantities and at comparatively low rates. The prices paid for glycerine when the whole output was acquired in the autumn of 1915 ranged from £59 10s. to £87 per ton, according to quality, and were based upon a large transaction of late date. In the free markets, prices fluctuated during the war between £300 and £185. The supply of glycerine was thus obtained at a relatively low cost, but British soap makers represented that they were unable to compete with foreign firms, which were able to make large profits upon their glycerine transactions. Accordingly, in March, 1916, they were protected against competition in the home markets by an order prohibiting the importation of soap. In 1918 special arrangements had also to be made to enable ammonium sulphate makers to continue agricultural sales at the controlled price when the cost of production had advanced considerably. The prices were arranged in four grades for agricultural, munitions, industrial and export purposes, and arrangements were made through the Sulphate of Ammonia Association for an equal division of profits among all dealers.

The methods used for providing the various materials for explosive manufacture are described in detail in the chapters which follow.

[1] Hist. Rec./H/1500/4.

CHAPTER II.

COAL-TAR PRODUCTS.

I. Dependence of Explosives Supply on Coal-Tar Products.

Picric acid and trinitrotoluene, the two most important high explosives employed by the British services, are manufactured respectively from the raw materials, phenol and toluene. These are two of the many valuable chemical substances obtained by distillation of coal-tar. In time of peace, such products are used in the manufacture of dye-stuffs, an industry which had its birth in England and afterwards, by blind neglect, was allowed to pass into the hands of German chemists. In August, 1914, therefore, the Germans were in the fortunate position of being able to turn with ease the vast resources of a flourishing coal-tar industry to the production of high explosives. In England, although large quantities of coal were being carbonised every year, a general lack of interest in the synthetic dye industry was responsible for the fact that the tar distillers had never considered it worth their while to utilise to the utmost the chemical resources of the coal. With the outbreak of war, the supply of coal-tar products assumed a new and unexpected importance.

II. Orders in Council Prohibiting Export.

It was at once apparent that materials from which explosives could possibly be derived must not be allowed to leave the country. During the first two months of war, provision was made for the restriction of export by a series of Orders in Council. On 3 August, 1914, a proclamation was made under the Customs and Inland Revenue Act, prohibiting the export from the United Kingdom of benzol, coal-tar and toluol. Benzol, another of the distillation products of coal-tar, was of importance from the point of view of explosives supply because the commercial product usually contained a high percentage of toluene and also because the benzene itself offered a starting point for the preparation of supplies of synthetic phenol, when the natural supplies should cease to be adequate.

On 5 August, 1914, a further proclamation, made under Section I of the Exportation of Arms Act, 1900, made illegal the export of war-like stores, which included phenol, nitrotoluene and picric acid, to all foreign ports in Europe and on the Mediterranean and the Black Sea, with certain exceptions.

On 8 September, 1914, an order, made under Section II of the Customs Exportation Prohibition Act of 1914, stipulated that nitrotoluene, coal-tar products employed in dye manufacture, dyes and

dye-stuffs obtained from coal-tar should not be exported to any destination whatever. An additional order on 25 September, 1914, excepted aniline and aniline salts from this restriction.

III. Formation of Committee on High Explosives.[1]

During the first three months of war the position with regard to the supply of coal-tar products for the manufacture of high explosives was very unsatisfactory. With a view to helping the manufacturers who were about to undertake to supply trinitrotoluene, the Contracts Department of the War Office instituted an investigation into the possibilities of toluene supply. Their efforts to obtain reliable data were, however, hampered by the receipt of conflicting information, and they found that it was almost impossible to get any knowledge of the true facts. It was alleged by the firms who were supplying trinitrotoluene for military purposes that the supplies of toluene were being held up by speculators, and that the orders prohibiting export of coal-tar products were being contravened. The dye industry was in direct competition with the explosives manufacturers in the race for raw materials. Tenders for toluene, issued by the Contracts Department to 100 firms in order to test the market, produced only 12 offers for insignificant amounts, which did not equal in all one month's requirements for the army, the navy and the Allies. The French, Russians and Belgians, who called almost daily on the Contracts Branch, were in despair, and stated that if Great Britain, the country standing first in productive capacity, could not find a means of obtaining supplies for them, it would mean nothing less than disaster.

In the month of November, the responsibility for maintaining an adequate supply of high explosives and of the raw materials for their manufacture was assumed by the newly-established Committee on High Explosives,[2] which was constituted for that purpose under the chairmanship of Lord Moulton. Mr., afterwards Sir Keith, Price, joined the staff of the Committee in December, 1914, and became specially responsible for organising the supply of coal-tar products until his appointment as Deputy-Director General of Explosives Supply in March, 1916. The work of the Committee, with regard to raw materials, included the acquisition for Government use of the normal output of toluene and phenol, the improvement of output of these products from coal-tar and the institution of new methods of supply.

IV. Acquisition of Normal Output of Toluene and Phenol.

(*a*) Power taken to Requisition Output of Raw Materials, November, 1914.

The urgency of the position with regard to the supply of raw materials for high explosives, was discussed at the first meeting of the Committee on 16 November, 1914, when it became evident that the entire resources of the country would be required to meet the

[1] Hist. Rec./H/1520/11. [2] Vol. X., Part IV, p. 22.

military demands. On 20 November, therefore, the Committee decided to recommend that Parliamentary powers should be taken to secure the entire output of toluol and to requisition existing stocks of toluol, as shown by the producers' returns to the Board of Trade, beginning with the larger stocks. On 25 November a Government amendment was added in Committee to the Defence of the Realm Consolidation Act, which received the Royal Assent on 27 November, 1914.[1] By this amendment the Army Council was given power either to requisition existing stocks or to take from any factory, during the period of the war, the whole output of any substance required for national defence.

(*b*) CONTROL OF COKE-OVEN AND TAR DISTILLERS' TOLUOL.

Whilst the powers to be taken by the Committee were still under discussion, the Director of Army Contracts issued to certain coal-tar producers circulars,[2] dated variously 25 and 27 November, stating that the Secretary of State considered it necessary to take possession of all the supplies of toluol available in the United Kingdom, and intimating that a representative of the Contracts Department would call on the firms with a requisitioning order. In the meantime, firms were requested to obtain the written authority of the War Department before making deliveries.[3] This requisitioning, however, was never carried out, as greater powers were obtained almost immediately, on the passing into law of the Defence of the Realm Consolidation Act.

On 27 November, 1914, Lord Moulton issued a memorandum, analysing very clearly the difficulties of the situation and outlining the course of action which was afterwards adopted. Toluene was obtained at the beginning of the war from gas undertakings, and also from those coke-ovens possessing special plant for the recovery of the tar from the gases distilled from coal in the coking process. Only about 20 gas undertakings and about half of the coke-oven undertakings, however, themselves extracted its various constituents from the tar. The actual production of toluene was therefore mainly in the hands of the distillers, to whom the crude tar was sold. Any attempt, however, to deal with the problem by requisitioning the total output of the tar distillers would only have resulted in placing the tar producers in a position to run up the prices of the tar and so create a market against the distillers, and, therefore, against the Government. Moreover, a wholesale requisitioning policy would have completely upset the existing course of trade, thereby alienating the goodwill of just those persons whose co-operation was essential to the success of any plan designed to raise the production of toluene to its fullest extent. Lord Moulton therefore proposed that, in order to disturb the trade as little as possible, circulars should be

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[1] *Parliamentary Debates*, 1914 (*H. of C.*), LXVIII., 1274.
[2] Appendix I. [3] HIST.REC./H/1520/11.

issued to both tar producers and tar distillers, taking, for the period of the war, that portion of their output which was not already covered by existing contracts. All firms would then be required to make a detailed return of their engagements to supply toluene. In the case of those producers who sold their entire output of tar, no interference would be necessary since the control exerted with regard to the distillers would suffice to secure the toluene. The contracts entered into by the tar distillers would, however, require a closer supervision. In the event of the supplies eventually reaching either the Government itself or a recognised explosives manufacturer under contract with the War Office, no difficulties would be raised, but, should the supplies prove to be destined for other uses, the fulfilment of the contract could be prohibited under the Defence of the Realm Consolidation Act. In this way, Lord Moulton considered that it would be possible to acquire the total output of toluene with the minimum dislocation of trade.

In pursuance of this policy, letters were drawn up for circulation by the War Office to gas-works, coke-oven undertakings and tar distillers.[1]

The principal notice[2] was sent to all firms. It was a notification in the name of the Army Council requisitioning, for the period of the war, the whole output of the firms' undertakings in toluene or substances containing toluene, so far as they were not covered by existing contracts for sale or distribution. In order to interfere as little as possible with such contracts, the Council would endeavour to leave with the firms enough of their output to cover their commitments, subject to the requirements of national defence. Particulars of contracts, into which firms had entered before the date of the circular, were to be notified to the Secretary of the Committee on High Explosives, not later than 5 December. This notification was issued with covering letters, dated 3 December, which varied according to the nature of the firm.

To those gas undertakings and coke-oven undertakings, whose practice it was to sell their tar, a letter[3] was sent indicating that their surplus output of toluol and carbolic acid and substances containing these would be required, that the Army Council were informed that they did not treat their tar, and that, in these circumstances, it was hoped that their arrangements would not need to be interfered with, but that a prompt return of particulars as to their existing contracts was desired.

To the other coke-oven undertakings, a letter[4] was sent, notifying the commandeering of toluol and substances containing toluol, asking whether or not the tar was distilled on the premises, and, if so, whether only commercial benzol and toluol or the pure substances were manufactured, what was the capacity of the distilling plant and whether

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[1] 74/HE 50.
[2] Appendix II.
[3] Appendix III.
[4] Appendix IV.

or not the latter was fully occupied. Information was also desired as to the amount of crude benzol and light oils obtained, if the pure substances were not separated. The firms were also asked whether their plant included apparatus for recovering benzol and whether it would be possible to instal such plant.

To those gas-works which were distilling their own tar and to tar distillers a similar letter[1] was sent, except that the clause referring to benzol recovery plant was omitted.

A register was compiled from the returns made by the various firms and the existing commercial contracts were reviewed with a view to the modification of those which apparently interfered with the interests of British or Allied military requirements. A further circular[2] was issued on 15 December to those tar producers who did not distil their own tar, authorising them to fulfil present contracts, to negotiate new ones with tar distillers, and to continue small sales to other parties, provided that such sales did not in the aggregate constitute a substantial portion of their total output. Other firms were notified as to whether or not they might fulfil their individual contracts, further information being desired in all cases where the final destination of the toluene was not clearly indicated. A certain quantity of toluene, which was fortunately not more than about 400 tons per annum, was essential to the manufacture of dye-stuffs, and this quantity was allowed to be diverted from direct Government use.

The acquisition of the total output of toluene produced by the distillers did not, however, ensure complete control of that commodity. In the early days of the war the distillation of coal-tar was not carried sufficiently far to isolate all the toluene. The better distillers separated their tar in such a way that the benzol fraction, which preceded the toluol fraction, and the solvent naphtha fraction which followed it, each contained a considerable quantity of toluene. Most of the distillers, however, drove off the greater part of the toluene with the benzol fractions, which they sold as commercial benzol, largely used in England and France as motor spirit. The presence of the toluene improves the quality of this product by rendering it less liable to freeze. The same result can, however, be attained by addition of xylol or of solvent naphtha, not required for the manufacture of explosives. The amount of toluene thus allowed to escape in commercial benzol was frequently as high as 10 per cent., and, because of the enormous production of benzol, represented very nearly one half of the country's supply of toluene. The matter thus became very serious and it was decided by the Committee on High Explosives that the distillers must be compelled to recover this toluene before selling their benzol. A circular[3] was therefore issued on 17 December, indicating that no interference would be made with deliveries or sales of benzol or naphtha containing less than 3 per cent. toluol, but that the express authority of the Committee

[1] Appendix V. [2] Appendix VI. [3] Appendix VII.

must be obtained for the export of toluol, benzol, or naphtha, and for all deliveries within the realm, which contained more than 3 per cent. toluol.

The efficacy of these arrangements depended very largely upon the methods used for determining the toluene-content of benzol. A difficulty immediately arose owing to the fact that there was no method for ascertaining this except by long and tedious fractionation. A standard form of test was therefore issued by the Committee on 24 December, 1914. The firms were informed that, if 95 per cent. of the sample under examination was obtained as distillate below 84 deg. C., the benzol, from which it was taken, might be sold in the United Kingdom without a permit, provided that its specific gravity at 15 deg. C. gave a value between ·880 and ·890. If less than 95 per cent. of the sample was obtained as distillate, particulars of the amount obtained must be sent to the Secretary of the Committee on High Explosives, who would report whether or not a permit for sale or delivery without further purification would be given. A sample and particulars of the test should, in any case, be sent if a permit for export was required.

This test was found to be somewhat stringent and the matter was reconsidered, with the result that a revised form of test was issued on 11 January, 1915. The new test provided that benzol might be sold in the United Kingdom without a permit, provided that 95 per cent. was obtained as distillate under 90 deg. C., and that the specific gravity at 15 deg. C. lay between ·870 and ·890. A note was added to the effect that no objection would be made to the addition of solvent naphtha or xylol to benzol, with the object of lowering the freezing point, provided that the benzol had passed the standard test before the addition. The standard method thus introduced was worked out by Dr. H. G. Colman, who acted as chemical adviser on coal-tar products.[1] The actual testing of samples took place at one of the laboratories of the Institute of Chemistry, which was placed at the disposal of Dr. Percy E. Spielmann for this purpose in January, 1915.[2] At this laboratory about 39,000 samples were eventually tested and numerous new methods were evolved.

The immediate result of the restriction placed upon the sale of products containing more than 3 per cent. of toluene was to cause an accumulation of benzol in quantities above the country's capacity for redistillation. Several firms made representations to the authorities that their stocks of benzol were rapidly accumulating beyond their storage capacity and that, in a very short time, their works would have to cease production.[3] In these circumstances they asked for leave to dispose of benzol containing more than 3 per cent. of toluene until the distillation capacity could be increased to

[1] HIST. REC./R/1500/14, p. 37; 1510/1. [2] 74/HE/70. [3] 74/B/39.

meet the demand. In order, therefore, to avoid congestion and to secure the goodwill and co-operation of the trade, permits were given where the proportion of toluene present was not substantial, but, in every case, full particulars were required as to the percentage of toluene and the destination of the benzol concerned, and warning was given that the granting of concessions of this kind could not be long continued. Some confusion then arose because of the fact that licences to export benzol and solvent naphtha were being independently issued by the Privy Council and the Committee on High Explosives, and certain discrepancies prevailed as to the conditions under which these licences were granted, resulting in delays in shipment. In the circumstances it was essential that such delays should not take place, and an arrangement was accordingly made whereby all questions regarding the granting of licences were referred directly to Lord Moulton's Committee and all permits issued by that Committee were accepted without further investigation by the Customs and Excise authorities.[1]

As a result of these measures, contracts which secured the whole of the country's output of toluene were negotiated by the Government during the winter of 1914-1915. A generous price was fixed in order to stimulate production, 3s. (or 3s. 4½d.) per gallon being paid for pure toluene. Though high in comparison with normal home prices, this price compared very favourably with those ruling in the United States, the alternative source of supply. The majority of the contracts were not, however, for pure toluene but for commercial toluol, and in these cases the price was fixed at 3s. per gallon for the toluene contents and 10d. per gallon for the benzol residues. At first, great difficulties were experienced in finding sufficient refining plant to deal with the commercial toluol, but, by the end of 1915, the refining capacity of the United Kingdom had been increased by 800 per cent., and the output of pure toluene was, in consequence, greater than that of the commercial toluol.

(*c*) CONTROL OF NATURAL PHENOL.

In the months preceding the formation of the Committee on High Explosives, difficulties, not only in obtaining supplies of toluene, but also in obtaining supplies of natural phenol (carbolic acid), were reported to the Contracts Department. Tenders for the manufacture of picric acid were issued to six firms during the last week of July, 1914. One firm, unable to obtain the raw material required, was compelled to decline manufacture altogether. Orders were placed with the remaining five firms but deliveries of the explosive were very much delayed. The manufacturers complained that large stocks of carbolic acid were being held up by the distillers with a view to inflating prices, and they asked that steps might be taken to induce the carbolic acid producers to sell at a reasonable price. In response to these complaints, the Department first issued a list of possible sources of carbolic acid supply, and on 8 August suggested that the manufacturers should communicate with those of the carbolic producers, who were asking unreasonable

[1] C.H.E./1508/4 A.

prices, explaining that the Government hoped that the willing assistance of the holders of raw material would obviate the necessity for enforcing the powers just taken for requisitioning stores under the Army (Supply of Food, Forage and Stores) Act. The price of phenol steadily advanced, however, and the manufacturers again complained of the difficulties in the situation towards the end of October.[1]

Nevertheless, after the formation of the Committee on High Explosives, Lord Moulton did not consider that it would be wise to take any steps under the Defence of the Realm Consolidation Act, interfering with the sales of natural phenol. Since export was prohibited, there was very little demand for carbolic acid except by the picric acid manufacturers who were, therefore, bound to obtain the greater part of the output eventually. Any attempt on the part of the Government to purchase phenol in the open market would, of necessity, have caused the price to advance still further. The loss of a small percentage of the country's output of phenol was not nearly so serious a matter as the leakage of toluene, since plans for the production of synthetic phenol were already under consideration, whereas the natural toluene could not be supplemented synthetically. Lord Moulton was able to report[2] in January, 1915, that the phenol situation had adjusted itself satisfactorily, and that the picric manufacturers were having no difficulty in supplying their requirements from the open market.

In April, 1915, however, it was decided that the Government should purchase the entire output of phenol. The market was then comparatively steady and no dislocation of trade was caused by the transference of contracts from the picric manufacturers to the Government. The negotiations were facilitated by the limited number of firms concerned. A generous price (1s. 3d. per lb.) was agreed upon, in order to stimulate production, and the whole output of the six carbolic makers was taken over for the period of the war. The virtual control, which had previously existed, was thus replaced by a direct control, in conformity with that in operation in the case of toluene.

A small percentage of phenol was reserved to meet the requirements of the Army Medical Department and also the essential needs of hospitals and pharmacists for medical purposes. The remainder was distributed amongst the explosives manufacturers.

Whilst these measures for the acquisition of the total output of toluene and phenol were still incomplete, the Committee on High Explosives was merged in the newly-established Explosives Supply Branch of the War Department (A6) in January, 1915. Five months later this organisation was taken over by the Ministry of Munitions and was, thereafter, known as the Explosives Supply Department. Lord Moulton was appointed Director-General of Explosives Supply.[3] The measures which had already been introduced by the Committee on High Explosives were carried to completion by these successive departments without any break in continuity.

[1] Contracts/A/2598. [2] Hist. Rec./R/1520/23.
[3] Vol. X., Part IV, p. 29.

V. Measures Taken for the Improvement of Output.

As soon as the schemes, whereby the Government obtained entire control of the country's resources in toluene and phenol, had been put into operation, attention was directed towards the question of improving the output of coal-tar products, both in coke-oven undertakings and in gas-works. The coke-oven proprietors were urged to extend their undertakings and to instal benzol recovery plant in the existing ovens, whilst the gas companies were asked to scrub their gas for benzol and toluol. This section of the work was under the direction of Sir Keith Price.

(*a*) Stimulation of By-Product Coke-Ovens.[1]

Before the war, the installation of coke-ovens was regarded as an essential feature in the equipment of a colliery, because it afforded a means not only for the development of power but also for the transformation of the waste duff or small coal into a valuable product. In about half of the coke-oven undertakings in the United Kingdom the only by-product produced was ammonium sulphate. The tar was, in some cases, sold to a tar distiller, in others, it was given to the coke-oven contractor in part payment for his services; and, in yet other cases, it was used in the preservation of roads. The aromatic hydrocarbons passing over with the gases were burned and therefore lost. The proprietors of the remaining coke-oven undertakings were in the habit of distilling their own tar, and some of these, more alive than the others to the possibilities offered them in the carbonisation of coal, had installed special plant for the recovery of benzol from the gases produced in the coking process.

From the returns made by the proprietors in reply to the circular of 3 December, 1914, an analysis of the position was made. The desirability of utilising to the utmost the resources of the coal was pointed out in a personal approach to all those concerns without a recovery plant, with the result that, one by one, they were induced to instal, at their own expense, such a plant for the scrubbing of their gas. At the end of 1916, the Explosives Supply Department was able to report that, out of 8,426 ovens in operation in the United Kingdom, only two batteries, totalling 60 ovens, were without a recovery plant. This measure, which retrieved from absolute loss a very considerable quantity of benzol and toluol urgently needed for military purposes, was of the utmost importance in that it represented the first step towards establishing the coal-tar trade in the United Kingdom on a satisfactory basis, scientifically and economically.

The resultant increase in the production of crude benzol helped to accentuate the need for an increased refining capacity, which came into being as a result of the restriction on the sale of benzol containing more than 3 per cent. of toluene, imposed in December,

[1] Hist. Rec./R/1500/6; Hist. Rec./H/1510/1.

1914. The situation was, at first, extremely difficult, but, by the end of 1915, the rapid multiplication of plant for rectifying the crude material had proved sufficient for dealing with the country's requirements.

The measures taken to stimulate production in the coking industry did not stop short at this point. The coke-oven proprietors were urged to extend their undertakings by the addition of new batteries of ovens. When war broke out, there were many such batteries in course of erection, and help was given in accelerating their completion. In certain instances production was stimulated by allowing the firms concerned to write off against excess profits 30 per cent. of the cost of extensions. During the war, nearly 1,000 ovens were added to the 7,126 which existed in 1914.[1] A table showing the development of benzol recovery appears in Appendix XVIII.

In addition, a system of inspection was established whereby the industry might be controlled with a view to speed, economy and efficiency in production. The coke ovens were grouped in the following districts :—(1) Durham and Cumberland ; (2) Lancashire, Staffordshire and Cheshire ; (3) Yorkshire and Derbyshire ; (4) Wales.

Each of these districts was placed in the charge of an inspector whose duty it was to keep in touch with the producers in his area, to give any advice and help in his power and to report whenever the ovens were not being run satisfactorily. The constant visits of inspection had a very good effect, and a remarkably high degree of efficiency was attained by the coke-oven firms, whose output at the end of the war had reached 90 per cent. of their working capacity. Had hostilities been prolonged, however, it would have been impossible to maintain output at so high a standard, as the ovens would necessarily have needed a great deal of repair and relining.

(*b*) Relations with the Gas-Works.

The position with regard to the recovery of benzol and toluol in gas-works was somewhat different. In the coke-oven undertakings, the loss was without object of any kind and was due only to lack of recovery plant. It was, therefore, ruthlessly eliminated. In the gas undertakings, however, a very considerable proportion of benzol and toluol was allowed to pass into the gas with the deliberate intention of improving the quality of the main product of manufacture. Though the gas-works of the country contributed only about one-sixth the quantity of crude benzol obtained from the coke-oven undertakings, it was estimated that the recovery of the toluene, ordinarily allowed to escape in the gas, would provide an additional 5,000 tons per annum for the manufacture of explosives. It was manifestly essential that so productive a source of supply should not be overlooked. The position was explained to the gas companies, and a very ready response was made to the appeal for the recovery of the toluene.

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[1] The relations with the coke-ovens as regards steel production are described in detail in Vol. VII, Part II.

In the larger works, the installation of special plant was required and the system adopted was that of oil-washing. The gas was scrubbed with some form of "gas" or "creosote" oil, from which the lighter fractions were periodically removed by distillation. By this process, which resembled that employed by the coke-oven firms, the whole of the benzol and toluol was extracted, the candle-power of the gas was reduced by 50 per cent. and the calorific value by 4–5 per cent. The process was started in 12 of the largest works in March, 1915, and was gradually adopted by others throughout the succeeding months of the year. The State bore the cost of erecting and operating these plants, which were worked by the gas companies under the supervision of a representative of the Department stationed at Birmingham. The supply of materials and despatch of products was organised through a single firm acting as the Government's agent.[1]

In the smaller works a system of tar-washing was introduced.[2] A very ingenious suggestion, made by Dr. Carpenter of the South Metropolitan Gas Company, resulted in the adoption of a process requiring very little alteration in plant, whereby the gas was brought into close contact with a stream of tar passing through any washing or scrubbing plant which could be spared from ammonia washing. By efficient washing, the illuminating power of the gas was only reduced by about one candle power and its calorific value by about 2–3 per cent., whilst the output of toluene from the works was at least doubled. In November, 1915, the Explosives Supply Department was able to report that the process was in operation in about 600 gas undertakings in the United Kingdom, comprising almost every works where the arrangement of the existing plant permitted its adoption.

A system of inspection was introduced, whereby the country was divided into seven areas, each with a representative gas engineer. These areas were subdivided into counties or districts, each of which was placed in the charge of a supervising engineer. Laboratories, intended to serve as testing stations for works in their areas, were established at the Universities of London, Glasgow, Leeds, Newcastle, Birmingham and Manchester. Each works was required to send, at stated intervals, two samples of tar, one taken from the untreated crude tar and the other from the tar used in the gas-washing process. The increase in the toluene content was then ascertained, and, in cases where the result was unsatisfactory, a report was made to the district engineer, who investigated the difficulties and advised accordingly. Both engineers and manufacturers displayed the greatest keenness, and the results were in the highest degree satisfactory.

In order that the standard of quality of the gas should be maintained at its normal level, the Explosives Supply Department agreed that the benzol recovered by the gas-washing process should be returned to the gas, together with an additional amount provided by the Government and equal in quantity to the toluene removed. In August, 1915, however, it was recognised that, because of the

[1] HIST. REC./H/1500/4. [2] HIST. REC./R/1500/6.

growing demand for benzol for explosive purposes, the department would no longer be able to provide this extra supply and, in addition, would require the whole amount of benzol recovered from the gas. It therefore became a matter of the utmost urgency to find an enricheners to take the place of the benzol. No substance with an equally high efficiency could be obtained, but a special spirit of sufficiently low boiling-point, which could be imported from the East by the Asiatic Petroleum Company in the required quantities, proved acceptable to the gas undertakings and was therefore adopted.

Within a few weeks, however, difficulties again arose because of the shortage of shipping. All the available tonnage was required for the transport of Borneo petroleum, designed for use as an additional source of toluene supply. The Government was, therefore, obliged to limit the gas undertakings to a definite ration of gas oil. The position, in consequence, threatened to become serious. The gas companies were required by law to produce gas whose illuminating power should reach a standard laid down by the Board of Trade. On the other hand, they were asked by the Government to remove from the gas those constituents contributing most largely to its illuminating power. In order to afford them protection in case they should be unable to comply with the Board of Trade regulations a formal letter[1] was issued to the gas companies in November, 1915, requiring them, under the Defence of the Realm Act, to scrub their gas and undertaking to relieve them of any forfeiture or other legal consequences arising out of the lowering of quality caused thereby. A copy of this notice, accompanied by a letter inviting their assistance in the protection of the gas companies, was issued, at the same time, to the local authorities interested in the supply of gas from each undertaking.[2]

It was perfectly clear, however, that, after the war, when the Government protection had been removed, the gas companies would be obliged to scrap the benzol recovery plants, which they had installed at their own expense, in order to supply gas of a sufficiently high candle power. The Gas (Standard of Calorific Power) Act was, therefore, passed in August, 1916, empowering the Board of Trade to issue to gas undertakings orders substituting a calorific standard for the illuminating standard until that time in general use. Since the removal of benzol and toluol affects the calorific power in very much slighter degree than the illuminating power, it was hoped, by this means, to enable the gas undertakings to continue, by the use of their war-time plant, the extraction of an appreciable quantity, though not the whole, of the benzol from the gas, after peace was declared. Orders were issued under the Act to all undertakings where recovery plants had been erected, directing them to supply gas of a calorific power of not less than 500 Board of Trade units. It was understood, however, that this standard should, like the illuminating standard, be subordinate to the Government instructions during the war.

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[1] Appendices VIII and IX. [2] Appendix X.

During the period that followed, many gas companies were obliged, partly because of a shortage of coal, to supplement their supplies of coal-gas by the addition of water-gas with a calorific value of only 305 Board of Trade units. At the same time, the ration of gas-oil was admittedly insufficient to bring up the value to the required standard. Indeed, the shipping crisis was so acute that the Board of Trade and the Explosives Supply Department together conducted a thorough investigation into the circumstances of each gas undertaking and then issued a licence for that amount of gas-oil which, as far as it was possible to estimate, would enable a mixed gas of only 470 Board of Trade units to be supplied.

Nevertheless, until the beginning of 1918, the quality of the gas was unchallenged. On 1 February, 1918, however, the Portsea Island Gaslight Company was prosecuted[1] by the Portsmouth Corporation for not maintaining its gas supply at the required standard and was convicted and fined on each of 16 counts. The Treasury Solicitor was asked by the Minister of Munitions to represent the Portsea Company in an appeal against the decision of the court. Meanwhile, a feeling of insecurity was aroused in the other gas undertakings and the National Gas Council made a request for further protection. It was felt that some step must be taken at once to safeguard the position of benzol supply and to reassure the gas companies, who might consider that they had a serious grievance against the Minister of Munitions, should the Portsea decision be upheld, in that he had assumed by his letter of November, 1915, powers which he did not in fact possess. It was decided that a regulation under the Defence of the Realm Act would best meet the case and such a regulation was accordingly issued on 11 May, 1918.[2] In addition, new instructions were sent to the gas undertakings with regard to the extent to which the gas must be scrubbed, partly in order to afford them proper protection and partly to provide against abuse of that protection. In the meantime, the Portsmouth Corporation was given an assurance that the Minister of Munitions considered that no responsibility rested with the gas company and it was, therefore, agreed that the appeal should be dropped in order to avoid litigation between the Corporation and the Government.

No further protests were raised against the depreciation in quality due to the removal of benzol and toluol from the gas, and the processes of oil and tar-scrubbing were continued throughout the war.

VI. Introduction of New Methods of Supply of Toluene and Phenol.

The remaining part of the work of the Explosives Supply Department with regard to the raw materials, toluene and phenol, was concerned with the introduction of new methods of supply to supplement the output of these substances obtained by the distillation of coal tar.

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[1] 74/P/579. [2] D.R. Regulation 8 G. (see Appendix XI).

(*a*) Distillation of Toluene from Borneo Petroleum.[1]

Early in December, 1914, Sir Marcus Samuel, the Chairman of the Asiatic Petroleum Company, informed the First Sea Lord that the French Government was negotiating with the Shell Oil Group for supplies of Borneo petroleum, a substance singularly rich in toluene. He urged that steps should be taken to reserve some portion of the oil for the use of the British Government, in consideration of the release from Admiralty service of the tank vessels essential to the French project. In addition, he pointed out to Lord Moulton that, for many years past, large quantities of the spirit had been distilled by the company at their Rotterdam works and that the toluene extracted had been used by the Germans for the manufacture of explosives.

Lord Moulton immediately instituted investigations into the practicability of extracting the toluene in this country. An analysis of a representative sample of the spirit showed that it contained—

16 per cent. benzol benzine (61 per cent. benzol ; 39 per cent. benzine or petrol).
16 per cent. toluol benzine (61 per cent. toluol ; 39 per cent. benzine).
43 per cent. automobile benzine.
25 per cent. mineral turpentine.

Consideration showed that difficulties might be anticipated with regard to the shipment of the spirit, the provision of proper rectification plant and the disposal of the petrol remaining after the extraction of the toluene. The company had placed 20 of their tank steamers at the disposal of the Admiralty and they were, in consequence, short of transport facilities. The distilling plant must necessarily be capable of rectifying the crude material with great exactitude in order to prevent the serious dangers which arise from the presence of tri-nitro-benzol in the finished explosive. Moreover, the company would incur risk of serious loss, unless they were given some assurance that an outlet would be found for the petrol residue.

It was decided that these difficulties were not sufficiently serious to prevent the extraction of toluene from Borneo petroleum in the United Kingdom and could be overcome by the chartering of foreign tank vessels, the removal of the company's Rotterdam distilling plant to England and the negotiation of contracts with the Admiralty and the War Office for the supply of petrol to the Forces. A provisional agreement between the company and the Explosives Branch was, therefore, drawn up on 13 January, 1915. This agreement was, of necessity, considerably modified before the contract, for 5,000 tons of Borneo petroleum per month, was finally signed at the end of April.

It was decided that a distillery should be erected at Portishead, on land owned by the Port of Bristol. The advantages offered by this site were the nearness of deep water, facilitating the transport of the toluol benzine, and the existence at Portishead of tankage, capable of

[1] 74/A/6 ; 74/HET/144 ; 74/A/84 ; Hist. Rec./R/1500/6.

ready extension and already owned by the Asiatic Petroleum Company. The removal of the stills and fractionating columns from Rotterdam to Portishead was carried out soon after the provisional agreement was decided upon. The dismantling process was begun on 30 January, 1915, and the plant was conveyed by sea to Thames Haven and thence by rail. The erection of additional tankage at Portishead was begun on 2 February, 1915. The workmen necessary for the erection of the Dutch plant were brought from Holland and returned thither when the work was completed. The distillery was working to its full capacity day and night by 3 April, 1915. The capital expenditure up to a given maximum was defrayed by the Secretary of State and the distillery was operated by the company, as agents for the Government. Payment was made at the rate of £32 10s. per ton of pure toluene and 10 per cent. on the working costs of operating the factory. The company undertook to supply toluol benzine containing not less than 50 per cent. of pure toluene. By the nitration of this product, mono-nitro-toluene was separated from the benzine residue. This preliminary nitration was carried out in a factory erected at Oldbury, near Birmingham, under the supervision of the Asiatic Petroleum Company and afterwards transferred to the Department, becoming an integral part of the Oldbury T.N.T. factory. It was in complete working order by 25 May, 1915, and was then able to keep pace with the output of the Portishead distillery. At the end of June, 1915, it was decided that a second distillery, with half the capacity of the first one, should be erected at Barrow-in-Furness. A corresponding mono-nitration factory at Sandycroft was designed to act as a complementary factory to the T.N.T. plant then being erected at Queen's Ferry. The new installation, as a whole, was intended to act as a stand-by to Portishead, in case of a breakdown, or as a means of increasing the output of toluene, should additional Borneo petroleum be available.

The importance of the introduction of this new source of supply cannot be over-estimated. The country's resources were eventually increased by 8,000 tons of toluene per annum, a quantity equal to the total pre-war production in Great Britain. The Department was able to supply certain small quantities to the Russian and Belgian Governments. In addition, a considerable reserve was built up in the United Kingdom and storage depôts were erected at Manchester, Chester, Huddersfield, Selby and London. The position at the end of 1915 was regarded as exceedingly satisfactory.

(*b*) Manufacture of Synthetic Phenol.[1]

From a very early stage of the war it was realised that, since the supply of toluene was entirely dependent on its occurrence in nature, any deficiency in raw materials for explosives purposes must be met by the manufacture of synthetic phenol from benzene or from some derivative of this substance. The British chemical manufacturers

[1] 74/B/114.

were, however, entirely unacquainted with the working of the processes involved, as well as with the character and construction of the technical plant required. It was recognised, therefore, that a large amount of research would be required before the industry could be established on a sound basis and that development would necessarily be slow. In view of these facts, Lord Moulton gave early consideration to the matter. The possibilities of manufacture in this country were reviewed by the Committee on High Explosives in November, 1914, and the first contracts for 60 tons per week in all were placed in January, 1915, with three private firms. Further contracts were negotiated in the succeeding months with three other firms. In two cases, the plant was installed at the expense of the Government. The manufacturers met with varying success in the new venture. One firm—Read, Holliday & Sons—was able to start production in July, 1915, and was closely followed by Messrs. Brunner Mond & Company and the South Metropolitan Gas Company. The achievements of Messrs. Brunner Mond, in particular, were of outstanding merit. They undertook the manufacture, at the request of Lord Moulton, in February, 1915. In March, they offered to contract for a supply of 20 tons per week, and in September, their average weekly output was 20-23 tons. In October, they informed the Explosives Supply Department that they were prepared to extend their plant with a view to increasing their output to 80-100 tons per week. In August, 1916, their weekly production had reached 100 tons.

Considerable difficulties arose, however, in the case of certain smaller and less experienced firms. Messrs. H. N. Morris & Company were entirely unable to make a success of the process at their works at West Gorton, in spite of the help of one of the successful firms.[1] The Chemical Products Company were equally unsuccessful at a factory at Sutton Oak. In consequence, the Department was obliged to take direct control of these works under the Defence of the Realm Act as from September, 1915, and May, 1916, respectively. Under the new régime, the factory at West Gorton reached its maximum of 21 tons a week in February, 1917, whilst that at Sutton Oak averaged 4 tons daily in March, 1917.

In October, 1915, the need for synthetic phenol had become so acute that it was decided to erect a Government factory, with a capacity of 10 tons per day, at Ellesmere Port. Construction was slow and production was delayed until May, 1917. At first, the product was disappointing in yield, though good in quality. The efficiency rapidly improved, however, and in March, 1918, the output was 70 tons per week.

Meanwhile, pending the completion of this factory, the weekly output of synthetic phenol from the other works steadily increased from an amount equal to that of the natural product in January, 1916, to three times this amount in August of the same year.

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[1] The South Metropolitan Gas Company.

The results thus obtained in a hitherto untried branch of chemical manufacture were thoroughly satisfactory and reflected considerable credit on the initial experimental work carried out by the various firms. The industry was, of course, in existence in France at a much earlier date, so that the Department was able to acquire a certain amount of information with regard to the processes in use on the Continent, but the greater part of the knowledge required had to be gained by actual working experience, and by intensive research by the Explosives Supply Department and several of the Universities.

The successful establishment of the synthetic phenol industry completed the department's arrangements for obtaining a maximum output of toluene and phenol for the manufacture of tri-nitro-toluene and picric acid. Measures had, however, to be taken to ensure an adequate supply of benzol to the synthetic phenol makers and it was, therefore, necessary to control this substance in addition to phenol and toluene.

VII. The Control of the Benzol Position.

(*a*) Purchase of Total Output of Standard Benzol.

In the early months of the war, the value of benzol from the point of view of British explosives supply was dependent only on the amount of toluene which could be extracted from it. It was, therefore, necessary in December, 1914, to forbid its sale should it contain more than 3 per cent. of toluene,[1] but, otherwise, dealings within the realm were not interfered with. The export of benzol had been prohibited at the outbreak of war,[2] in order to prevent its use as a starting-point for explosives manufacture by enemy countries, less fortunate than ourselves in their supplies of phenol and toluene ; and in December, 1914, it was again emphasised that, except under permit from the Committee on High Explosives, benzol must not be exported.[1] To the French, however, a large supply of benzol for the manufacture of synthetic phenol was essential because of their lack of the natural raw materials, phenol and toluene. The War Office, therefore, undertook to supply to the French Government at least 2,300 tons of benzol per month for the period of the war. This minimum quantity was raised in the autumn of 1915 to 2,800 tons. Considerable quantities were also supplied to the Russian, Belgian, and Italian, Governments. A small quantity was employed in Great Britain in the early attempts to manufacture synthetic phenol, and, with the introduction of oil and tar washing in the gas-works, a further quantity was set aside for gas-enrichening. The remainder was consumed either in the manufacture of dye-stuffs, or as motor-fuel.

In May, 1915, however, it was recognised that the manufacture of synthetic phenol would have to be undertaken on a large scale in order to meet the requirements of the new shell programme. It therefore became necessary to control the benzol position, if supplies to the Allies were to be maintained.

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[1] Appendices II. and VII. [2] See above, p. 11.

The plan, which had proved so successful in the case of toluene, was again adopted. Contracts were made with manufacturers for their whole output of standard benzol throughout the war. Dealers were required to consult the Department on all prospective deliveries and, although certain quantities were allowed for motor use, it was intimated that this arrangement could not be continued indefinitely. The negotiation of these contracts was begun in May-June, 1915. By August, the demands for benzol had greatly increased and the Department was obliged to discontinue the provision of this substance as a gas-enrichener. It was pointed out that a considerable amount was still being used for motor spirit, for which purpose efficient substitutes could be obtained. A notice[1] was, therefore, drawn up, informing manufacturers that the Minister of Munitions had found it necessary to requisition the whole production of standard benzol in the country and directing them to complete delivery only in case of contracts already entered into with the Government. The negotiation of contracts was, meanwhile, carried out according to plan. The ordinary course of trade was not interfered with where it could be shown that the supplies of benzol ultimately reached the Government. The dealers were, however, obliged to give full information and to obtain written authority for each individual transaction. The country was divided into areas, North-East Coast, Midlands, London and District including South Coast, and Scotland. Mr. Keith Price visited the central places in the different areas to confer individually with the various producers. The larger firms were first induced to agree to a price for their whole output, other than authorised dealings, and the smaller firms were then persuaded to accept the same terms. The price varied slightly with local conditions. Only a few firms refused to enter voluntarily into contract and the output of these was taken under the Defence of the Realm Act.

By the end of the year, the negotiation of contracts was complete, and the use of benzol as a motor-fuel was entirely prohibited. Its use for the manufacture of dye-stuffs could not be eliminated, but the amount released through the Board of Trade for this purpose was cut down as far as possible. In September, 1916, this quantity represented about one-ninth of the whole production.

The measures taken to increase the output of benzol have already been described.[2] In August, 1916, the Department was able to report that storage depôts had been erected at Hull, Middlesbrough, Newcastle, Leith, Birkenhead, Penarth and London; and that no difficulty was experienced in supplying the synthetic phenol makers as well as the Allied Governments.

(*b*) Restrictions to Ensure Refining of Crude Benzol.[3]

The arrangements made in 1915 related to standard or commercial benzol, a product midway between crude benzol and refined benzol. The crude benzol was left free until 1917, since, in the normal

[1] 74/HEB/23. [2] See above, pp. 19–23.
[3] 74/HEB/81; *Manual of Emergency Legislation*, 1917, p. 81.

course of events, it was passed on to the refiners, whose output was under control. It was found, however, that certain small quantities leaked away, more especially from the coke ovens, without being refined. There was reason to believe that these quantities were purchased by unscrupulous persons, who extracted the benzol contents for improper use, such as the manufacture of petrol substitutes. An order, known as the " Benzol and Naphtha Order, 1917,"[1] was, therefore, issued under the Defence of the Realm Act, on 29 August, subjecting all dealings in crude benzol, crude naphtha and light oils, containing recoverable quantities of benzol and toluol, to licences issued by the Director of the Raw Materials Section of the Explosives Supply Department. Crude benzol and crude naphtha, in the meaning of the Order, included those products, whether obtained by the distillation of coal-tar or by extractions from coal-gas, together with the benzolised wash-oil obtained by the gas-washing process. Light oils were those obtained by the distillation of coal-tar. By an Order issued on 31 December, 1917,[2] and known as the " Naphtha Order, 1917," similar stipulations were made concerning dealings in crude solvent naphtha, solvent naphtha and heavy naphtha, obtained by distillation of coal-tar or by extraction from coal-gas.

By this means, leakage of crude products containing recoverable amounts of benzene or of toluene was prevented, and the benzol position was brought completely under control.

In order that the crude tar and its higher-boiling fractions should be controlled with an efficiency equal to that obtaining with regard to the lower-boiling fractions, a further series of orders was drawn up during this period, and may conveniently be described here, although their main bearing is upon the problem of fuel-oil supply, which is described elsewhere.

On 13 July, 1917, orders were issued subjecting all dealings in creosote and other oils to licence, prohibiting their use for treating wood or road-making except under permit from the Ministry, and requiring from consumers returns as to the sources from which their oils were obtained and details concerning their use.[3]

The " Coal Tar Order " of 4 September, 1917,[4] was designed to ensure that the maximum quantity of tar should be distilled and that the creosote fraction, which was urgently needed by the Admiralty for oil-fuel, should be recovered. It stipulated that tar obtained by the destructive distillation of bituminous material, other than in blast furnaces (whose output was already controlled), should not be supplied without a licence from the department, except to a recognised tar-distiller, who would undertake to distil his entire purchase.

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[1] Appendix XII., No. 4. [2] Appendix XII., No. 8 ; 74/HET/429.
[3] Creosote and Other Oils Orders, 13 July, 1917 (Appendix XII., Nos. 2, 3).
[4] Appendix XII., No. 5.

This Order was superseded by the Tar (Coal and Water-Gas) Order of 31 December, 1917.[1] The new Order included the tar obtained by carburetting water-gas, since this material yields, on distillation, a large proportion of oil, eminently suitable for fuel. It stipulated that the tar-distiller, receiving supplies of tar without licence, should undertake to distil entirely to pitch, and it prohibited the use of tar by the producer for firing, steam-raising or heating purposes, except under licence from the Department.

By the "Tar Oils Order," 23 October, 1917,[2] possession was taken of those fractions especially suited for use as fuel, and future dealings in them were subjected to licence. In the meaning of the Order, the term "tar oil" included creosote oil, green oil, sharp oil, anthracene oil and other oils produced by the distillation of coal-tar, coke-oven tar, producer tar, water-gas tar, and Mond gas tar. In addition, maximum prices for these oils were fixed.

The Order was superseded, however, by the "Tar Oils Control Order, 1918,"[3] which was issued on 1 February. The new Order extended the meaning of the term "tar oil" to cover all products not already covered by the "Benzol and Naphtha" and "Solvent Naphtha" Orders, unless the pyridine content exceeded 50 per cent., and included the products obtained by distillation of oil-gas tar.

By means of these Orders, the control of coal-tar products, other than ammonia, was finally brought to completion. The later measures, from the Coal-Tar Order of 4 September, 1917, onwards, were an essential part of the general scheme for developing the home production of fuel-oil, which is described elsewhere.[4]

VIII. Ammonia Supply.[5]

(*a*) Subsidising of Ammonia Liquor, 1916.

Whilst the supply of raw materials for picric acid and tri-nitro-toluene was, from the outset, a matter of the utmost importance, the production of ammoniacal liquor by the distillation of coal was, until 1916, of very little moment. Before the war, the ammonia production of the United Kingdom was very considerably in excess of the demand; there was very little market for the weak liquor ordinarily obtained; and the cost of transport in many cases made its sale a matter of loss rather than gain to the producers. Many of these, in consequence, reduced the quantity of ammonia recovered to the minimum, and in Devon and Cornwall they even threw the liquor into the sea. The greater part of the ammoniacal liquor, which was sold, was used for the manufacture of ammonium sulphate for agricultural use.

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[1] Appendix XII., No. 7. [2] Appendix XII., No. 6.
[3] Appendix XII., No. 9. [4] Vol. VII., Part III.
[5] 74/Ammonia/24; 74/Ammonia/210; 74/HEA/236; Hist. Rec./H/1510/1.

Early in 1916, however, the manufacture, on an increasing scale, of new explosives, such as ammonal and amatol, created a demand for ammonium nitrate. The laborious process of converting the industrial sulphate into ammonia and thence into the nitrate did not give a very satisfactory product, and, moreover, the acid required for the original manufacture of the sulphate was urgently needed in the production of the finished explosives. The method for the direct conversion of the sulphate to the nitrate had not at that time been worked out. The obvious solution of the difficulty lay in the substitution of the use of concentrated ammonia liquor for that of ammonium sulphate in the preparation of ammonium nitrate.

The manufacture of the latter substance was undertaken by a group of factories under the supervision of Messrs. Brunner Mond & Company, Ltd., who were authorised to contract, on behalf of the Government, for supplies of ammonia liquor. In June, 1916, however, the Explosives Supply Department, having found that the plant designed by Messrs. Brunner Mond was not capable of producing a liquor of the strength and purity required, took over the organisation of supplies, entrusting this responsibility to the Explosives Concentrated Liquor Section.

Designs for suitable plant were examined, and five were adopted, all of which were capable of producing 25 per cent. ammonia. Ammonia producers were then urged to instal plant of the type best suited to their works and to change over from the production of sulphate to that of concentrated ammonia. As an inducement to this end, the Department undertook to pay two-thirds of the cost of the plant in every case where the production was equal to, or greater than, 150 tons of sulphate per month. The entire output of liquor was bought by the Department at the standard price of 11s. 6d. per unit percentage of ammonia ; 12s. 6d. per unit was paid, however, until the extra price had reached the amount of the grant made by the Government. The right of inspection, with a view to the maintenance of a high efficiency in output, was claimed by the Department in all its contracts.

On 31 October, 1916, the Minister took power under Defence of the Realm Regulation 15 C. to require, from all producers of coal-tar or coke-oven by-products, particulars of their output, working costs, sales, stocks, and purchases. The by-products concerned included particularly tar, carbolic crystals, benzol, toluol, and also ammoniacal liquor and sulphate of ammonia.[1]

The coke-oven firms and gas-works responded readily to the appeal made to them to increase the yield of ammonia, and the results were very satisfactory. In addition, several of the large Scottish shale oil companies were also induced to instal concentration plant, although it was more to their own advantage to continue the making of sulphate. Firms which were equipped with concentration plant were,

[1] Coal-Tar or Coke-Oven By-Products Order, 31 October, 1916, Appendix XII. No. 1.

in many cases, able to deal with the supplies of dilute liquor from firms without the facilities for concentration. When the scheme was introduced, the monthly production of ammonia liquor was not quite 500 tons. The contracts placed by the Department amounted to about 10,000 tons per month.

(*b*) AMMONIA SUPPLY IN 1917 AND 1918.

During the years 1916 and 1917, the demand for ammonium sulphate for agricultural purposes steadily increased because of the loss of sodium nitrate, which had previously been used as a nitrogenous fertiliser, and also because of the increased acreage under cultivation. The need was met by restricting export which, until that time, had been very considerable. Towards the end of 1917, however, it became evident that the estimated requirements for 1918 for agricultural and explosives use combined could not be met by the country's ordinary production of ammonia. The increase in the number of coke-oven plants had barely added to the output because of the increasingly inferior quality of coal available, and supplies were no longer adequate. Steps were, therefore, taken to control both ammonium sulphate and ammonia.

The price of ammonium sulphate had already been unofficially controlled since June, 1917, by the Food Production Department of the Board of Agriculture, as the result of negotiations with the Ammonium Sulphate Association, to which nearly all the makers belonged. It was formally controlled by the Fertiliser Prices Order of 30 April, 1918,[1] which officially adopted the prices already settled with the Association, and, in addition, subjected dealings in ammonium sulphate to licence. The cost of manufacture of ammonium sulphate had, however, increased very considerably with the rise in price of raw materials and labour, and investigation early in 1918 showed that some compensation was due to the producers if they were to continue their agricultural sales at the controlled price. A subsidising scheme was, therefore, introduced by the Explosives Supply Department,[2] and four prices for sulphate were arranged: (*a*) agricultural controlled price, against which the subsidy was paid; (*b*) munitions price, arranged by contract; (*c*) industrial price; (*d*) export price.

The sulphate sold for industry and export was bought by the Sulphate of Ammonia Association at the munitions price and re-sold at a profit. The profits on all dealings were then equally divided among all the makers to compensate for any unfairness of division of the more favourable classes of sale, which would otherwise have arisen.

The control of price of ammonium sulphate was followed on 17 May, 1918, by the Ammonia Control Order,[3] under which the manufacture and delivery of ammonia and ammoniacal products, other than the sulphate, were regulated by licence. Permits were issued for the month of June with recommendations that a reduction in the

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[1] Appendix XII, No. 10. [2] 74/Ammonia/1026.
[3] Appendix XII, No. 11.

consumption of ammonia, for purposes other than munitions and agriculture, should be made. From July onwards, the supplies for non-essential industries were severely curtailed and stringent restrictions were placed upon the export of all forms of ammonia.

At the same time, the problem of increasing the output was seriously considered by a specially chosen Ammonia Advisory Committee. One remarkable step was the provision of a travelling sulphate plant to collect and work up ammonia liquor in agricultural districts such as Devon and Cornwall. Inquiries were also made into the conditions of working at all the ammonia-producing plants, and technical advice was given as to the means whereby avoidable loss in yield could be diminished. The general standard of efficiency was in consequence very much improved.

In addition, the possibilities of extending the sources of supply of ammonia were considered. The production of synthetic ammonia was, admittedly, too big an undertaking to be of any immediate value in increasing output. Arrangements were made, however, for the production of benzol and ammonia from Norfolk peat.

When the Armistice was signed, the ammonia position was fairly easy and there was every reason to believe that the agricultural requirements would be fully met. The travelling sulphate plant did not come into operation until after the Armistice and it was eventually sold as scrap; but the tightening-up of efficiency in ammonia production was, of course, a permanent improvement of importance in the development of after-war chemical manufacture. The general relations with the fertiliser industry will be considered below.[1]

IX. Effect of Control on the Coal-Tar Industry.

The measures which have been described were taken with the sole object of meeting the high explosives requirements of the country during the war. They were, from this point of view, brilliantly successful. The output of raw materials was enormously increased and a remarkably high standard of efficiency in production was attained. The effects of control were not, however, of a merely temporary nature, ceasing to be of value when war was over. A stimulus of incalculable importance was given to chemical industry in the coal-tar trade, which was established, for the first time in Great Britain, on a sound basis economically and scientifically. The coke-oven undertakings were extended and recovery plants were installed so that full advantage might be taken of the resources of the coal. The refining of the tar was carried very much further in order that those products which were of value in the manufacture of explosives should be separated as completely as possible. The various processes were carried out under expert direction and inspection with a view to speed, economy and efficiency in production. Avoidable loss in every direction was carefully eliminated, until at the end of 1916 the manufacturers were straining to the utmost their efforts to obtain the maximum yield of coal-tar products.

[1] See below, Chap. III.

The importance of this general increase in efficiency lies in the fact that those very products, which were required for war purposes, are also the starting products required for the peace-time preparation of synthetic dye-stuffs, drugs, perfumes and essential oils in which, before the war, Germany excelled. The country's coal supply is, from the chemical point of view, its greatest asset. With a new enthusiasm and a new standard of efficiency in the coal-tar trade, a new opportunity is given to build up a flourishing chemical industry in Great Britain and to retrieve the position which has been lost through neglect during the last fifty years.

CHAPTER III.

ACIDS.

I. Introductory.[1]

Service explosives are formed by the action of nitric acid on various substances. This action is usually carried out in the presence of sulphuric acid, which absorbs the water produced by the reaction and acts as a medium for the reaction. Sulphuric acid is also required for the manufacture of nitric acid. Hence the supply of high explosives and propellants during the war was vitally dependent on an adequate supply of nitric and sulphuric acids, and therefore of nitrate of soda, sulphur and pyrites (sulphur ore), the essential raw materials for these acids. In the early months of the war the problem to be dealt with was not lack of these raw materials but insufficiency of plant to produce the necessary acid. Chemical plant cannot be erected speedily unless it is of very simple and well-known design, and difficulties in supplying special parts may always occur when the demand suddenly increases. Thus, for instance, the special earthenware that was employed in the Valentiner type of nitric acid retorts, was made by only two or three English firms, since it was a specialty of certain German works, and the Volvic stone used in Kesslers and Gaillard towers was only obtained from France. Such difficulties may be lessened by varying the ordinary procedure, *e.g.*, in the first case by erecting the Guttman type of nitric acid plant, of a different construction from that of the Valentiner, and in the second case by erecting the rather less efficient cascade type of concentrator or by substituting acid-proof bricks in place of Volvic stone for the lining of the Gaillard towers and the Kesslers; but such substitutions may not always be possible. In cases where it became necessary to design new plant for processes not hitherto used in this country, *e.g.*, the Grillo contact process for producing oleum, much arduous work was involved, requiring skilled chemical engineers.

Nitric acid, which became of great importance owing to the large scale manufacture of military explosives, is used in peace-time in the manufacture of industrial explosives and dye-stuffs, small quantities being used for etching and pickling purposes and for metallic nitrates, but its pre-war consumption was not extensive, amounting in the three years before the war to an average of only about 14,000 tons (expressed as 100 per cent. acid) per annum. Of this about 5,400 tons was used for the manufacture of explosives which were exported, 2,800 tons for explosives used in mines and quarries, 3,000 tons for the manufacture of munitions and the remaining 2,800 tons for other industrial purposes.

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[1] Based chiefly on Hist. Rec./R/1512/3 and 4.

It was manufactured in this country before the war by the treatment of Chile nitrate with strong sulphuric acid by the well-known retort process, and indeed this remained the standard method of manufacture in Great Britain throughout the period of the war, though schemes for producing it synthetically were launched.

The acid which is of importance in peace-time industries is sulphuric acid, the sulphuric acid industry being the key industry of the chemical trade. The principal consumers of sulphuric acid before the war were (1) the superphosphate trade, (2) the sulphate of ammonia trade (3) the alkali trade, including sulphates such as sulphate of copper, (4) dyes, explosives, general chemicals, galvanising, metal refining, etc. The fertiliser industries, namely, superphosphates and sulphate of ammonia, absorbed about three-fifths of the sulphuric acid production, while hardly any industry in the country was independent of it.

The acid consumed was of varying strengths, the term "sulphuric acid" covering oleum, *i.e.*, sulphuric acid containing an excess of sulphur trioxide in solution; R.O.V., or rectified oil of vitriol, and C.O.V., or concentrated oil of vitriol, of about 94 per cent. strength; B.O.V., or brown oil of vitriol, of about 80 per cent. strength, and chamber acid of about 65 per cent. strength. Oleum, however, is frequently spoken of as distinct from other sulphuric acid.

The pre-war production of strong acid, *i.e.*, oleum and R.O.V., was consumed in the manufacture of dyes, explosives, and nitric acid, and in tar washing, oil refining, wool carbonizing, dyeing and bleaching, metal pickling and mineral water manufacture. The oleum was produced by three firms possessing plant for making it by the contact process, *i.e.*, a process involving the combination of the SO_2 formed by burning sulphur or pyrites with more oxygen to form SO_3 in the presence of a catalyst, platinum being used for the purpose. The oleum plant capacity was about 25,000 to 30,000 tons per annum. The R.O.V. was manufactured from chamber acid by concentration. In a few cases Gaillard towers were used for the purpose, but for the most part Kessler plants or iron pots of the Dreyfus type were used, while shortly before the war cascade units using silica basins had begun to be adopted in the Lancashire area for making clean acid for the textile industries.

The pre-war production capacity of weak acid, *i.e.*, B.O.V. and chamber acid, was about 1,000,000 tons per annum calculated as 100 per cent. acid, its industrial uses being for superphosphates (300,000 tons), sulphate of ammonia (280,000 tons), hydrochloric acid (66,000 tons), bleaching powder (80,000 tons), iron pickling (70,000 tons) seed crackling (50,000 tons), oleum (40,000 tons), copper sulphate (25,000 tons), dyeing and bleaching (25,000 tons), etc. The chamber acid was obtained by mixing SO_2, produced from burning sulphur or more frequently by the combustion of pyrites, with nitrogen oxides and steam in large leaden chambers, the SO_2 being thus oxidised to SO_3. B.O.V. was obtained from the chamber acid by concentration.

The huge increase in the manufacture of explosives, consequent on the outbreak of the war, necessitated the use of large quantities of sulphuric acid, the greater part being required in the form of strong acid, particularly oleum, for which previously there had been a comparatively small demand in this country, since it was only used in certain special industries.

As hydrochloric acid was also used to a limited extent in the manufacture of explosives, and in such industries as the manufacture of glycerine and bleaching powder and chlorine, the outbreak of the war necessitated an increase in the demand for it, but manufacturers succeeded in adjusting their supplies to meet this. It was produced as a by-product in alkali manufacture by the action of sulphuric acid (chamber acid) upon common salt.

II. Development of the Control over Acid Manufacture.

(*a*) Efforts to Meet the Increased Explosives Programme.[1]

At the end of November, 1914, the Committee on High Explosives —then acting in an advisory capacity only—realised the importance of the development of the production of nitric acid, since the demand for nitric acid in war-time is out of all proportion greater than the demand for it in peace-time. The Committee soon began to acquire executive authority, and at a meeting on 10 December, 1914, when the supply of nitric acid was considered, it was decided to approach Messrs. Chance & Hunt, of Oldbury, a well-known firm of acid manufacturers, with a view to arranging for the supply of 15 tons of nitric acid weekly to a certain firm contracting for T.N.T., and authority was given Lord Moulton, the Chairman of the Committee, to push on with plans for the installation of Guttman nitric acid plant at some suitable place.

During the first few months of the following year, the scheme for extending the firm's nitric acid plant at Oldbury materialised as an adjunct to a project for a State factory for T.N.T., which they undertook to manage. The supply of nitric acid was to be made on a contract basis, the Department making a grant towards the plant, which was to produce 30 tons of 91 per cent. to 93 per cent. nitric acid weekly.

Contracts for the production of nitric acid were, however, unusual. Since nitric acid is difficult to transport, its manufacture was mainly undertaken by explosives manufacturers themselves, unless they were hampered by lack of space or other difficulties, and the policy pursued by those responsible for explosives supply was to encourage every explosive firm to manufacture its full requirement of nitric acid. The plant necessary for the production of nitric acid from sodium nitrate and sulphuric acid is comparatively simple, and such that it can be easily erected, and, until extensions of plant made them self-supporting in this respect, explosives manufacturers made their own arrangements with outside makers of nitric acid to meet any deficiency.

[1] See Hist. Rec./R/1500/6, R/1500/10, R/1510/7, H/1520/11, R/1512/5, H/1510/2, R/1512/4, R/1512/3, and X/240.

In order to safeguard the position, it was arranged to have a productive capacity of 100 tons per week of nitric acid at Oldbury, in addition to the total requirements of the factory for T.N.T. manufacture, and in October, 1915, a contract was under discussion with a firm manufacturing explosives for the erection of additional nitric acid plant beyond that necessary for their own picric acid requirements, this being then in course of erection in accordance with a picric acid contract dated 11 October, 1915. The additional plant was erected in order that they might supply two explosives contractors who could not cover their own nitric acid requirements, or any contractor as the Government should direct. The agreement was dated 4 March, 1916, and was for a plant capacity of at least 22 tons of weak acid per day. Government advanced £8,000 (two-thirds of the cost), this advance carrying interest and being repayable. At the same time, a capital grant (£2,692) was given for the erection of storage tanks, it being intended that nitric acid should be held in reserve against the risk of breakdown of plant. One other nitric acid contract was made in conjunction with one for the production of ammonium nitrate, but eventually only the latter was delivered.

The production of nitric acid in July, 1915, was approximately 4,300 tons; in August, 5,000 tons. It was developed to reach a total of approximately 20,700 tons per month early in 1916; while, during 1917, the total output amounted to 237,000 tons (expressed as 100 per cent. acid). The quantity used for purposes other than explosives manufacture remained substantially unchanged throughout.

In the early months of the war, dislocation of trade released sufficient sulphuric acid to meet the increased demands made for explosives, except in the case of oleum, for which there had been hitherto little demand. Of the three firms in the United Kingdom who possessed oleum plants at the outbreak of the war, one only (Messrs. Spencer Chapman & Messel) supplied oleum to the trade and to Waltham Abbey (the only Government factory consuming oleum); the two others (the Clayton Aniline Company and Messrs. Nobel's) producing it merely for their own consumption. The first of these had a plant of their own design, while the two latter had Mannheim, and Mannheim and Tentelew plants respectively. A fourth firm (Messrs. Kynoch, Arklow), had a Mannheim plant in process of erection, which was completed towards the end of 1915. The navy held a certain reserve of oleum for cordite manufacture at the outbreak of war; but the demand developed very rapidly. Not only was oleum imperatively needed for the production of high explosives, but the increase in the British manufacture of dye-stuffs was also raising an increasing demand for it in the dye industry. It was impossible at short notice speedily to put up plant which was unfamiliar to the majority of acid makers in this country. In order to obtain a sufficient store of oleum it thus became necessary to augment home supplies by imports, and recourse was had to overseas producers. In November, 1914, the Contracts Branch of the War Department

accordingly placed contracts in America and in Canada for deliveries in the early months of 1915. In some cases, deliveries continued throughout 1915 and the early months of 1916; but later Great Britain became independent of overseas supplies. The total amount purchased by the Government in America was about 27,000 tons, and in Canada about 16,000 tons. A contract was also made for 1,200 tons from Holland, and rather less than 200 tons was imported from Italy in exchange for benzol (by a contract dated 22 November, 1914). Besides this, overseas oleum contracts were made by private firms in Great Britain requiring oleum. The average cost of American purchases of 20 per cent. oleum was £4 16s. per ton f.o.r. works, naked, or about £12 per ton delivered, after allowing for losses in transit, which were very heavy in the earlier shipments.

While arrangements were being made for importing oleum, the output of existing plants in this country was being increased to the fullest extent by the use of concentrated acid as feed acid, and arrangements were being made with firms already possessing oleum plant to make extensions, and with some other firms who had not previously possessed oleum plants to erect them, so that they might produce oleum either for their own consumption or to sell to the Government. Contracts were made with a couple of firms for the supply of oleum during 1915, while contracts were entered into with several other firms for future supplies. Before the war, the average price charged at works for 20 per cent. oleum was just over £4 a ton. In the first contract made, the price fixed was £10 10s. per ton delivered. Later, the average price, f.o.r. maker's works, was between £8 and £9. In some cases, financial assistance was given to firms erecting oleum plants by means of allowances from Excess Profits in respect of their capital expenditure.

Further, it being evident that private makers could not meet the constantly increasing requirements of oleum, it was decided, early in 1915, that the lay-out of the Government factories then being erected for the manufacture of T.N.T. and cordite should include oleum plants. Accordingly, contact plants were erected at these factories (including the Royal Naval Factory at Poole), and it was arranged that the oleum plant at H.M. Factory, Queen's Ferry, should be of sufficient capacity to supply outside consumers in addition to satisfying the factory requirements. The type of plant at first erected was the Mannheim, which was chosen because the Mannheim plans were available, and the plant could be had, whereas there were no plans in the country for the Grillo—a better type of plant—nor could the necessary plant be bought ready-made. Later, Grillo plants were erected, and also Tentelew plants—this latter, like the Grillo, being a good type of plant, but taking long to erect. For the efficient working of all contact plants, platinum is required as a catalyst, and, at the request of the explosive supply authority, from May, 1916, onwards, no dealings in platinum were allowed without a licence under Defence of the Realm Regulation 30A.

The result of all these efforts to increase the supplies of oleum was that the production, which for the week ended 5 February, 1916, was 1,700 tons, was in the week ended 5 December, 1917, 8,750 tons, *i.e.*, at the rate of approximately 450,000 per annum, of which 300,000 tons could be ascribed to Government plants. Six months later, owing chiefly to reduction in the explosives programme, but partly to the increased efficiency at explosives factories, much less oleum was required, and production had fallen to 2,600 tons per week.

As, from the first, the Government required all and more than all the oleum available, not only for the production of land service explosives, but also for the use of the Admiralty, the whole output of private makers was purchased by the Government under contract, a part being allocated for Admiralty use, and oleum was never controlled under an Order, nor was a system of licences instituted, as was done in the case of sulphuric acid. Later, after the Government oleum plants had come into commission towards the end of 1916, and when the production of oleum was greater than the requirements of the Government, makers were allowed upon application to sell to trade purchasers, but until then all consumers of oleum, other than contractors who had their own oleum plants or in the early days imported from overseas, necessarily bought their supplies from the Government.

At the beginning of the war the few manufacturers of explosives obtained their supplies of sulphuric acid by direct purchase from manufacturers. As the explosives production increased their requirements were, for many months, met by the ordinary sulphuric acid makers who, owing to reduction in trade, were glad to find an additional outlet for their acid.

During the early part of 1915, it became necessary for the Department to examine very closely the available supplies of acid, and to invite manufacturers to increase their concentration plant in order to supply the acid in the form required by explosives manufacturers. On 7 March, 1915, the Advisory Committee on the Supply of Sulphuric Acid[1] was set up. It consisted of representatives of three of the most prominent acid manufacturers in the country. The Committee held meetings in various large towns, impressing upon manufacturers the urgent necessity of increasing the output of concentrated acid. There was no shortage of weak acid, the chamber plants in existence being capable of supplying all requirements, and up to October, 1915, the Ministry[2] held the view, largely supported by the Advisory Committee, that no increase in the production of chamber acid was required.

(*b*) The Tightening-up of Control.

Towards the end of 1915 it became evident that the future demands for explosives, owing to the great expansion of the gun ammunition programme, would involve the consumption of nearly half the total

[1] The Committee met from time to time during 1915-16, and occasionally in 1917; it was superseded by the larger Sulphuric Acid Advisory Committee appointed early in 1918. See below, p. 52.

[2] The Explosives Supply Branch of the War Office was taken over by the Ministry of Munitions, 23 June, 1915.

national production of sulphuric acid. The new sulphuric acid plant being erected at Government explosive factories was not yet ready and the problem to be faced was how to obtain this large quantity of acid with the least possible dislocation of trade. This problem was dealt with by the Acid Supplies Branch of the Explosives Supply Department, which had gradually come into being and of which Mr. Enfield, who had previously acted as Secretary to the Committee on High Explosives, was appointed director in October, 1915, Mr. Bailey, of the Alkali Staff, being loaned to it by the Local Government Board. In order that the distribution of acid among the various trades might be properly regulated it became necessary for the department to take over the control of the whole sulphuric acid trade. This incidentally resulted in the regulation of the production of nitric and hydrochloric acid, since in the production of both of these sulphuric acid was used.

During the last week of October, 1915, the concentrated acid production of the country was approaching 3,500 tons, but the consumption in explosives manufacture was extravagantly large, since many explosives factories, particularly picric acid works, were not provided with adequate plant for the re-concentration of spent acid.

It appeared that, on the basis of consumption of sulphuric acid for explosives, it would be practically impossible to increase the programme to the desired amount on the lines then being adopted, and the following lines of policy were suggested and finally adopted to improve the acid position quickly :—That all waste acid then being sold or run to drain or sea should be re-concentrated and used over again, and that the equivalent of three parts of concentrated acid to one of explosive should be aimed at as quickly as possible ; that, wherever possible, nitre-cake (a waste by-product from the manufacture of nitric acid) should be used in place of sulphuric acid for purely souring operations such as sewage fat separating and also for pickling operations ; that, instead of the large ammonium nitrate production being made from sulphate of ammonia, steps should be taken to erect concentrated ammonia liquor plants over the country,[1] and that the acid thus saved should be concentrated for explosives requirements ; that a general policy of increasing output on both concentration plant and chamber plant should be adopted and that the requirements should be spread over all the acid works in the country.

A campaign of economy was thus instituted during the winter of 1915, and concentration plants were erected wherever possible. In many cases they were put up at fertiliser works, thereby diverting acid from that industry. Contracts were entered into by the department, for the erection of both sulphuric acid and concentration plant, these contracts being for the most part of the same type, whereby the department undertook to purchase a certain minimum quantity of acid at an agreed price, such minimum quantity being based on the supposition that the profit obtained by its sale would just repay the firm for the capital outlay on new plant.

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[1] See above, p. 31.

The continued increase in the demands for sulphuric acid in explosives manufacture caused a rise in price, and at the beginning of 1916 there were evident signs that exorbitant prices were being asked. In view of this and of the necessity, both in the interests of explosive manufacture and of general trade, for exerting still greater control over the acid trade of the country (which hitherto had been controlled only by letters of request), it was decided to bring the whole trade within the scope of the Munitions of War Act. Accordingly, on 14 February, 1916, an order was made declaring acid works controlled establishments under this Act. About the same time, viz., 11 February, 1916, the Department issued a circular[1] fixing maximum prices for acid of the various commercial grades. These prices obtained until 30 December, 1916, when they were revised.[2] A system was also established of weekly returns from all acid manufacturers, showing the quantities of concentrated acid produced, and of monthly returns, showing the distribution of acid throughout the country in all manufacturing operations. Those from sulphuric acid makers were required from February, 1916, onwards, and those from nitric and hydrochloric acid makers from July, 1916, onwards, these latter being made necessary by the increased use by manufacturers of nitric and hydrochloric acid, consequent upon the Department's limiting the use of sulphuric acid. Since very careful supervision of the use of acid in explosives factories was essential in order to avoid waste, a similar system of statistical returns from each explosives factory was started. From data so obtained an acids programme was worked out in June, 1916, involving the erection of further plant. Some allowance for capital expenditure was made out of excess profits. The policy of the withdrawal of acid from general trade purposes, particularly from the manufacture of fertilisers, had been adopted as a temporary measure in order to keep pace with the rapid extension of explosive manufacturing plant. The policy was definitely changed as a result of the submarine campaign during the winter of 1916–17. Acids were no longer allocated to the explosive industry at the expense of fertiliser manufacture. From February, 1917, onwards any increased demand was met by further construction. Thus, extra Grillo units were erected at the National Explosives Factory, Avonmouth, over and above the actual needs of the picric acid section of the factory originally planned. Much of the plant erected at a later date was not required since the stringency of the tonnage position prevented the full development of the explosive and fertiliser programme.

Intervention was also found to be necessary as regards repairs. As a result of the general speeding up throughout the country, the manufacturers had endeavoured to avoid shutting down their plant for repairs during the summer, as was their usual practice. It was therefore decided to examine all acid plants throughout the Kingdom and ascertain their efficiency and the repairs necessary in order to maintain their efficiency. In November, 1916, a basis was agreed upon for meeting the cost of such repairs and renewals, a certain

[1] See Appendix XIII. [2] See Appendix XIV.

proportion of the cost being written off against the excess profits payable by acid manufacturers under the Munitions of War Act. The concentration plant already erected by this time exceeded the post-war requirements of the country. It was accordingly arranged in December, 1916, that firms should erect new concentrating plant, the cost of which was allowed out of excess profits.

During the period of the war, the chamber acid plant capacity of the United Kingdom was increased by about 300,000 tons[1] of sulphuric acid per annum, and of this figure two-thirds represented new acid plants which were not in existence before the war, and one-third represented increases to existing acid plant. The maximum output during a complete year, namely, during 1916, was approximately 1,200,000 tons,[1] but in March, 1917, when the production of chamber acid reached its highest point, the output was at the rate of 1,307,000 tons per annum. The output of concentrated acid also reached a maximum about this time, a weekly figure at acid makers' works in February, 1917, being at the rate of 460,000 tons[1] per annum. During 1917, it was found that owing to the increasing importance of economising shipping, a more complete control of the consumption of imported sulphur material and therefore of the use of sulphuric acid would be necessary, and under an Order, dated 29 May, 1917,[2] a more stringent and formal control was established.[3]

III. Intervention in regard to Consumption.

(*a*) Efficiency in Explosives Factories and erection of Recovery and Concentration Plant.[4]

In the early days of the war the main problem was to keep the output of explosives at the maximum figure and little regard was had to economy in the case of acids, but later the question of efficiency became of great importance. The returns sent in by the explosives trade showing their acid consumption and production of explosives gave a measure of their efficiency in respect to acid usage and at first this left much to be desired. No exact information is available as regards the consumption of sulphuric acid for the manufacture of high explosives during 1915, but it has been estimated from existing data that in October, 1915, explosives works were using about six tons of sulphuric acid[5] to each ton of explosive (T.N.T. and picric acid) and generally the recovery of waste acid at the various trade factories was either not provided for at all, or in cases where some provision for it was made the recovery plants were inadequate and inefficient, so that much nitric and sulphuric acid was lost. The

[1] Expressed as 100 per cent. acid.
[2] See Appendix XV., No. 1.
[3] See below, p. 47.
[4] Hist. Rec. R/1512/4; *2nd (Printed) Report on Costs and Efficiencies at H.M. Factories controlled by Factories Branch, D.E.S.*
[5] This sulphuric acid included that used for the production of nitric acid.

Acids Supply Branch accordingly sent letters to explosives manufacturers asking for economy in acid usages and went into the question of the equipment of private explosives factories with the necessary recovery plant. The result was that arrangements were made for the erection of many additional plants, all of which were completed in the summer and early autumn of 1916, the policy adopted being to discourage the supply of acid to explosive manufacturers who had not put up recovery plants.

In the case of picric acid, in December, 1915, there was no recovery of waste acid at all, and generally manufacturers were averse from attempting recovery because of the danger they anticipated from the small percentage of picric acid remaining in the waste sulphuric. Suitable plant was, however, adopted, the re-concentration of the waste sulphuric acid being accomplished in two stages. In June, 1916, about 27 per cent. was being recovered, and in June, 1918, about 77 per cent.

The necessity for the recovery of waste acid had from the first been recognised in planning Government factories, and the contract entered into with Messrs. Chance & Hunt, dating from 1 February, 1915, for the erection of the first national T.N.T. factory included the erection of the plant necessary for the recovery of waste sulphuric acid. In the large new Government factories whose erection was begun in the middle of 1915, adequate provision was made for the denitration of spent mixed acid and the subsequent concentration of the sulphuric acid thus recovered. In the administration of these Government factories particular emphasis was laid on the question of efficiencies and costs with the result that remarkable improvements were made in plant efficiencies resulting in a great saving in the use of raw materials. For instance, the average acid usages (in terms of 100 per cent. acid) at Government T.N.T. factories for the period June-December, 1916, were 0·64 tons of sulphuric and 1·29 tons of nitric per ton of T.N.T. produced, or, expressing the nitric acid used in terms of the sulphuric acid and sodium nitrate used in its production, a total of 2·71 tons of sulphuric acid and 1·98 tons of sodium nitrate; and the corresponding figures for the period January-June, 1918, were 0·41 tons of sulphuric and 1·04 tons of nitric acid, or 1·85 tons of sulphuric acid and 1·50 tons of sodium nitrate. Similar improvements were made in Government propellant factories, *e.g.*, whereas at Gretna 1·45 tons of sulphuric acid and 1·61 tons of sodium nitrate were used per ton of cordite for the period July-December, 1917, the corresponding figures for the next six months were 1·21 tons of sulphuric acid and 1·08 tons of sodium nitrate.

The result of these efforts in both trade and Government factories towards improving efficiency and providing for the recovery of spent acid may be illustrated by the fact that while in December, 1915, the average amount of sulphuric acid used at T.N.T. works, expressed as 100 per cent. acid and including that used for the production of the necessary nitric acid, has been estimated as from five to six tons of acid per ton of T.N.T., for the three months ending June, 1916, it was 4·36

tons, for the three months ending June, 1917, 2·23 tons, and for the three months ending June, 1918, it had fallen to 1·96 tons.[1] Since sulphuric acid is used in the production of nitric acid, these figures for the overall consumption of sulphuric acid depended largely on the nitric acid used and so reflect the economies effected in nitric acid usage and the efficiencies of nitric acid and denitration plants.

This improvement as regards consumption of acid in explosives manufacture, largely due to efficient working at Government factories, not only relieved the acid situation but also effected a great saving in national expenditure. Further details as to economies effected in the overall consumption of sulphuric acid in the manufacture of the principal explosives are shown below.

(*b*) Substitution of Nitre-cake for Sulphuric Acid and Liquor Ammonia for Ammonium Sulphate.[2]

Towards the end of 1915, the general decision was made to endeavour to bring about the substitution of nitre-cake for sulphuric acid in certain industries in order to effect an economy of sulphuric acid in general trade. Some steps had already been taken in this direction, when Messrs. Chance & Hunt undertook to use nitre-cake from the Oldbury T.N.T. factory in making salt cake, while the State paid the difference between cost of manufacture with this material and that under the firm's normal practice.[3]

Owing to the very large consumption of nitric acid in explosives work, nitre-cake, a by-product in the manufacture of nitric acid containing about 30 per cent. of sulphuric acid, was being produced in enormous quantities. With the exception of the consumption of a small quantity in the manufacture of hydrochloric acid, practically no commercial use had been found for it. It was regarded as a waste product, and in many cases as much as £1 per ton was being paid to contractors to remove nitre-cake and dump it on waste ground or run it into the sea.

As long as sulphuric acid was cheap and available in large quantities, manufacturers would not use nitre-cake, but owing to the efforts of the department its use was taken up in Yorkshire by manufacturers engaged in grease recovery from wool suds and in sewage precipitation, and this was followed by a very rapid extension of its use not only for souring operations but also for pickling operations in the metal trades, etc. By May, 1917, it was being used for industrial purposes at the rate of 225,000 tons per annum and its industrial use was later still further extended. Thus, at the end of 1917, the consumption of nitre-cake was approximately at the rate of 288,000 tons per annum, of which $\frac{1}{4}$ was used in grease recovery, $\frac{1}{4}$ in bleaching and dyeing, $\frac{5}{24}$ in metal pickling and cleaning and $\frac{5}{24}$ in hydrochloric acid manufacture, while $\frac{1}{24}$ was used in mineral water manufacture and $\frac{1}{24}$ in miscellaneous trade processes of a varied nature.

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[1] Hist. Rec./R/1512/9.
[2] Based chiefly on Hist. Rec./R/1500/10, R/1512/2, R/1510/7, H/1510/2.
[3] 74/C/79.

By urging manufacturers to use nitre-cake and in some cases withholding the supply of sulphuric acid where nitre-cake could be used as a substitute, quantities of sulphuric acid were liberated for purposes for which it was essential, while trades were kept going that would otherwise have stopped for want of acid. At the same time a big financial saving was effected, as a waste product of which the disposal was costly, had been converted into a marketable commodity at a price of over £1 per ton.

During the first three months in which the scheme was in operation (*i.e.*, to 31 March, 1916), no charge was made for nitre-cake supplied by Government factories; consumers could obtain all they required provided they took it away from the factory at their own expense. On 1 April, the price was fixed at 12s. 6d. per ton delivered in the Department's waggons at the nearest siding to the consumer, and this price remained in force until 3 August, 1916. On 1 September, 1916, the price was raised to 17s. 6d. a ton delivered as before, and this price was maintained until 1 January, 1918, when it was increased to 25s. a ton.

The total production of nitre-cake in the successive years 1916, 1917 and 1918 was respectively 304,271 tons, 431,122 tons and 289,668 tons. The corresponding figures of consumption were 155,369 tons, 252,857 tons, and 239,810 tons, *i.e.*, 51·1 per cent., 58·7 per cent., and 82·8 per cent.

The substitution of concentrated ammonia liquor for sulphate of ammonia in the manufacture of ammonium nitrate, resulted in further economy of sulphuric acid, the acid thus saved being concentrated for explosives requirements. The department induced sulphate of ammonia manufacturers to make this substitution, and in order to obtain the necessary supplies of concentrated ammonia liquor, arranged for the erection of concentration plant at gas-works, coke ovens and shale oil works. The working of the plant was left to producers, the concentrated liquor being purchased by the Department at a fixed price per unit of ammonia. The plant was paid for by the Department, either by means of a direct grant or by an addition to the unit price.[1]

The full saving of sulphuric acid contemplated was not, however, attained, for the crystallisation process adopted at H.M. Factory, Swindon, necessitated the use of ammonium sulphate as such, and consequently, when this factory came into operation (September, 1917), the quantity of concentrated ammonia liquor, of which the use was foreshadowed in 1916, had to be curtailed and replaced by ammonium sulphate.

(*c*) Rationing the Trade under the Sulphuric Acid Order of May, 1917.[2]

The system of controlling the supply of sulphuric acid and incidentally of hydrochloric and nitric acids, was gradually evolved. The Department had at first no legal power to enforce the carrying

[1] See above p. 31.

[2] Hist. Rec./R/1512/4 and 5.

out of its directions, but its instructions—*e.g.*, for preventing acid makers from delivering acid to consumers who were in a position to use nitre-cake as a substitute—were carried out for the most part, as though they had the force of law. The maximum prices fixed in February, 1916, and revised in December, 1916, to protect consumers against the tendency to run up the price of acid unreasonably, were observed, although in this case also the Department had no power to enforce its rulings.

By 1917, the position had altered somewhat as acid was abundant, but owing to the necessity for saving tonnage it was still desirable to restrict its use in cases where substitutes were available, and to control its production, use and supply generally. Under the Order, dated 29 May, 1917,[1] the rationing which had in fact been going on from February, 1916, was placed on a legal foundation, and the prices were officially fixed. Acid makers were also placed under a rigid control by means of a system of licences for making, using or dealing in sulphuric acid of all strengths up to 100 per cent. H_2SO_4 (*i.e.*, all sulphuric acid other than oleum). Since February, 1916, the Department had been receiving every month from acid makers and dealers detailed returns showing (*a*) the amount they made, (*b*) the amount they purchased, (*c*) the amount they used themselves, and (*d*) the amount they sold, giving the name of the firms they had supplied, the quantities they had supplied them with, and the use to which it had been put. Consequently, the licensing scheme caused little or no disturbance to the trade. The maximum prices were graded according to the varying strengths of the acid.

On 25 April, 1918, a circular letter was sent proposing a revision of the fixed prices in view of (1) the rise in the cost of labour and materials during the past months; (2) the estimated increased cost of labour and materials during the period in question; and (3) the increased cost of production per ton directly due to a reduction in the total quantity of acid manufactured. A scheme was put forward for adjusting payments made by the Government to contractors in accordance with varying restrictions on output. These revised maximum prices, which were to apply from 1 June, 1918, to 30 September, 1918, were embodied in the Sulphuric Acid (Amendment of Prices) Order of 10 May, 1918.[2] The prices were again revised on 8 November, 1918,[3] and the control of sulphuric acid continued until 31 May, 1919.

(*d*) Control of the Fertiliser Industry.[4]

In the middle of 1916, since the oleum plants which were being erected at Government factories were taking longer to complete than was originally contemplated, it became necessary to divert from the fertiliser industry a very considerable portion of acid in order to meet

[1] Appendix XV, No. 1. [2] Appendix XV., No. 7.
[3] Appendix XV., No. 11.
[4] Based chiefly on Hist. Rec./H/1510/2, R/1510/18.

the growing demand made by the increase in the explosives programme. The Board of Agriculture agreed that this step was necessary, and at the same time appointed a Fertiliser Committee, upon which the Acids Section of the Ministry was represented by Mr. Enfield. A few months later, the question of fertilisers was taken over by the Food Production Department of the Ministry of Food, to which several members of the committee had been transferred, and the Fertiliser Committee ceased to sit. The Board of Agriculture, however, subsequently formed a Food Production Department, and all questions relating to food production, including the supply of fertilisers, were re-transferred to it by the Ministry of Food.

In February, 1917, the control of the manufacture of fertilisers was transferred from the Board of Agriculture to the Ministry of Munitions, the main reason for this transfer being that sulphuric acid is the most important raw material in the manufacture of the principal fertilisers, ammonium sulphate and superphosphate. The Ministry thus became responsible for controlling the manufacture of superphosphates, ammonium sulphate and basic slag.

In March, 1917, an inter-departmental committee, representing both the Explosives Supply Department and the Food Production Department of the Board of Agriculture, was set up in order to co-ordinate the control of manufacture, for which the Explosives Department was responsible, and that of distribution, the responsibility for which belonged to the Food Production Department, but this end being accomplished within the next few months, the committee, though never formally dissolved, ceased to sit.

As a part of the policy of increasing the home production of food which had been adopted at the close of 1916, a very considerable increase of fertilisers was required. This altered the policy in regard to sulphuric acid, since it became necessary to provide sulphuric acid to meet not only the full demands for explosives but the demands of fertiliser manufacturers in addition. The completion of many of the Government acid plants greatly facilitated this change of policy.

As regards the manufacture of superphosphates, examination showed that the development of the submarine menace in February, 1917, had caused the importation of phosphate rock to fall off alarmingly. It was decided that the only way to ensure the importation of phosphate rock, and so to keep up the supply of superphosphates, was for the Government to become responsible for its importation. On 13 June, 1917, the Government authorised the importation of 50,000 tons per month for the manufacture of superphosphate, this quantity being approximately equivalent to that needed to keep existing superphosphate works fully supplied when working on maximum output.

By an Order, dated 20 August, 1917, the price of superphosphates of varying qualities was fixed,[1] and in the following November the

[1] See Appendix XV., No. 2.

same schedule of prices was applied to sales for export.[1] The problem before the Department therefore became one of increasing production of superphosphate up to the limit of 50,000 tons of phosphate rock per month and of enabling superphosphate manufacturers to carry on production on a basis which would allow them to sell at the fixed prices and make a reasonable profit.

In view of the fact that the price of sulphuric acid to superphosphate makers was already fixed, it became necessary to issue phosphate rock to them at prices consistent with the fixed prices of superphosphate. In order to do so, it was found that it would be necessary, having regard to the constantly increasing rate of freight, for the Department to take over the importation of the whole British requirements of phosphate rock. A section was accordingly established to carry out the shipping arrangements for the importation of this rock, and contracts with the various importers were made, the balance of existing North African contracts made by private firms being taken over and some being also purchased from America. After a close investigation of the cost of manufacture of superphosphate based on the maximum prices for sulphuric acid and present cost of labour, fuel, etc., and after consultation with an Advisory Committee representing the various branches of the trade, an issue price for phosphate rock delivered to manufacturers was fixed.

Having taken the step of fixing the price of superphosphates, it became necessary, since the price of ammonium sulphate had been the subject of an agreement between the Board of Agriculture and the ammonium sulphate makers (9 June, 1917),[2] to ensure that compound manures containing these two were not sold by manufacturers at excessive prices. This resulted in the issue of the Compound Fertilisers Order, 13 October, 1917,[3] which fixed the price of compound manures according to the value of their nitrogen, phosphorous and potash contents. This step was taken after consultation with the Food Production Department of the Board of Agriculture and with an Advisory Committee representing various sections of the trade.

Side by side with this work steps were taken to increase the production of basic slag, firstly, by the erection of additional grinding plant, and, secondly, by facilitating the provision of labour. The production of basic slag is independent of sulphuric acid, but as it is a phosphate manure which can largely replace superphosphates, the control of its production was important. The price of basic slag was fixed by agreement between the trade, the Food Production Department and the Explosives Supply Department. During the year 1917, an attempt was also made to develop home resources, by exploiting coprolite deposits. A coprolite working was established at Trumpington in Cambridgeshire, and began output in the following summer.

[1] Superphosphates Order, 17 November, 1917. These prices were revised by the Superphosphate (Amendment) Order, 1918, on 28 March, 1918 (Appendix XV., Nos. 4, 6).

[2] See above, p. 32. [3] Appendix XV., No. 3.

The policy of the Department was to maintain fully the supplies of sulphuric acid for the manufacture of ammonium sulphate, for use as a fertiliser. The production of ammonia was, however, limited by the capacity of the gas and coke oven industries; moreover, a large proportion of the ammonia so produced was needed for the production of ammonium nitrate. The steps taken for economising ammonium sulphate and increasing the yield of ammonia-producing plants have already been described.[1]

An Order,[2] dated 30 April, 1918, was issued relating to superphosphate, sulphate of ammonia and basic slag. An equalisation scheme was thereby applied to all three fertilisers and the prices of sulphate of ammonia and of basic slag were fixed. This order was followed by the revised Compound Fertilisers Order of 4 June, 1918,[3] which, while substantially the same as the order of October, 1917, widened the definition of what constituted a compound fertiliser. The control of fertilisers continued until 31 May, 1919.

IV. Control of the Raw Materials for Acids.

The supply of the sulphuric and nitric acids so vitally necessary for the provision of high explosives and propellants, was limited in the early days of the war by lack of available plant capacity rather than by any shortage of the necessary raw materials. Later, there was ample plant capacity, but the maintenance of adequate stocks of raw materials became a matter of growing concern, so that rigid economy in their use became essential; and when the shipping difficulty became acute, it was even necessary to cut down production in order to conserve stocks.

Not only were the supply and distribution of acids functions of the Explosives Supply Department, but as difficulties increased, it fell to them also to undertake the tasks of importing the necessary basic raw materials—*i.e.*, pyrites, sulphur and nitrate of soda—of distributing them to Government factories and to the factories of various private contractors, and of maintaining ample reserves to meet the demands of the whole country in the event of emergencies. Such a programme, involving heavy importations, necessitated close co-operation with the Transport Department of the Admiralty, and later with the Munitions Overseas Transport Department, and the Shipping Controller in arranging for tonnage; it also required a highly organised system of distribution, calling as it did for the transportation every week of many thousands of tons of raw materials from many ports to many destinations.

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[1] See above, pp. 30–33. [2] Appendix XV., No. 9.

[3] Appendix XV., No. 10.

(*a*) Pyrites.[1]

For the production of sulphuric acid Great Britain depended on the importation of large quantities of pyrites and sulphur, but the quantity of pyrites used was considerably in excess of the sulphur and provided about six-sevenths of the sulphur material used in this industry. Before the war, *i.e.*, in 1913, the annual imports of pyrites were over 780,000 tons. This pyrites was principally imported from Spain, and also in much lesser quantities from Norway. Ordinary Spanish pyrites contains approximately 46 to 48 per cent. sulphur, 45 per cent. iron, 2 per cent. copper. Under normal pre-war conditions the sulphur contents of the ore were sold by the pyrites mine owners to acid manufacturers, who roasted the ore in kilns, thereby removing the bulk of the sulphur and leaving residues containing approximately 61 per cent. iron, 3 per cent. copper, 3·5 per cent. sulphur. Under pre-war conditions almost the whole of the pyrites which was imported was cupreous, *i.e.*, it contained sufficient copper to make its extraction a profitable undertaking, and this was done either at works in this country belonging to mine owners or at other independent works. This process of extraction reduced the contents of the copper and of the sulphur in the residues below the limits necessary to comply with the requirements of the blast furnaces for the manufacture of steel. The copper was extracted by the so-called "wet extraction" process, and the resultant "Blue Billy" was briquetted by means of special plant attached to copper extraction works or steel works. In this way both the copper and iron contents of the pyrites were worked up and used.

In February, 1915, a Pyrites Sub-Committee, consisting of representatives of three of the largest firms handling pyrites, was set up by the High Explosives Committee to maintain large Government stocks in this country, as it was considered necessary to build up a reserve supply for the possible use of our Allies as well as of Great Britain. The executive work was carried out by Mr. Evans, of the shipping department of the Rio Tinto Company, under instructions from the Rio Tinto offices in Lombard Street. Mr. Fielding, the chairman of the Rio Tinto Company, was also chairman of the sub-committee. National stocks were laid down in different parts of the country. These were increased from time to time, reaching 250,000 tons in December, 1917. Shipments to this country were maintained by arrangements with the Admiralty, and later with the Ministry of Shipping. From these stocks emergency supplies were allocated to acid makers when necessary.

During the years 1915–16, shipments of pyrites were greatly increased over pre-war figures, and in order to obtain these increased supplies certain stocks of "washed pyrites" from which the copper content had been extracted were imported. The consumption of pyrites reached a maximum during the year 1916, when the supply

[1] Based chiefly on Hist.Rec./H/1510/2; R/1510/19; 74/HEP/232; 74/HEP/294.

of acid for explosives manufacture had largely to be maintained by the acid manufacturers of the country, and the only Government contact plants in operation were of the early Mannheim (pyrites burning) type. Later (beginning in the autumn of 1916) the Government Grillo plants came into operation, and as these used sulphur as a raw material they considerably reduced the consumption of pyrites.

In consequence of the increasing freight rates on imported pyrites, and having regard to the fixed prices of sulphuric acid, it became clear that if sulphuric acid manufacturers were to be enabled in the future to continue to produce acid at the maximum prices and make a reasonable profit, it would be necessary to issue pyrites to them at a price consistent with the maximum prices of acid. In consequence of this, and of the growing shortage of ships, it was decided that the Department should undertake the importation of the whole of British requirements of pyrites from Spain and elsewhere, amounting to about 1,000,000 tons per annum. In July, 1917, the Pyrites Sub-Committee was dissolved and negotiations were undertaken with the various mine owners for the purchase of the necessary quantities of pyrites. After consultation with a Pyrites Trade Advisory Committee which was nominated by the Department as representing the sulphuric acid makers and was formed in August, 1917, arrangements were made to issue pyrites to the acid makers at a price to be determined after investigation of the cost of manufacturing acid.

This arrangement came into operation on 1 January, 1918, and included a scheme for the utilisation of the pyrites residues for the manufacture of steel. The original issue price to consumers was a flat delivered rate of 1s. per unit of sulphur for pyrites containing 45 per cent. of sulphur or over, with specified allowances for pyrites of less than 45 per cent. sulphur. The cinders resulting from burning the pyrites were to be stored by the consumers free of charge and re-delivered free of charge to the Department. The arrangements made did not apply to home-produced pyrites.

When the details of this scheme were settled the Pyrites Trade Advisory Committee was dissolved, on 22 December, 1917, and it, together with the Advisory Committee on the Supply of Sulphuric Acid,[1] was superseded by the Sulphuric Acid Advisory Committee formed in January, 1918. This advisory committee was constituted on somewhat broader lines than its predecessors, the recently-formed Association of British Chemical Manufacturers being asked to nominate nine members and the Fertilisers Manufacturers Association, four.

The use of washed pyrites containing too low a copper content for economical use in copper extraction plants had resulted in an accumulation of considerable stocks of burnt pyrites cinders at the various acid manufacturers' works, nor were there sufficient copper extraction plants existing to deal with the large quantities of cupreous pyrites used. In view of shipping difficulties these cinders were very

[1] See above, p. 40.

valuable on account of their iron content. In order, therefore, to utilise the iron content of the pyrites and so to reduce the shipping tonnage required for the importation of iron ore, the Department made contracts for the erection at Middlesbrough and Swansea of sintering plants each capable of treating 600 tons of pyrites cinders a day, so as to get them into condition for direct charging into a blast furnace. In addition, certain extensions were made to copper extraction plants in existence in the country, and wherever possible cinders were sold to iron masters possessing briquetting plants. Owing to labour and other difficulties it was not, however, possible to attain during the period of the war the maximum consumption of pyrites cinders. Another attempt to exploit home resources was made in 1917, when the Pyrites Mines at Trefriw were developed under the control of the Explosives Supply Department.

The shipments of pyrites to the United Kingdom reached a maximum in 1915, when 1,008,000 tons were imported, but a part of these shipments was on behalf of the copper smelting industry. The estimated consumption for acid manufacture in the year 1916 was 922,000 tons, while in 1918 it fell to 744,000 tons. Some attempt was made to increase the production of home-mined pyrites and this rose from 7,000 tons in 1917 to 21,000 tons in 1918. It was, however, for the most part, of a low grade.

(*b*) Sulphur.[1]

The average net imports of sulphur for the two or three years prior to the outbreak of the war was about 18,000 tons per annum. It was consumed in the production of sulphuric acid, gunpowder, sheep dip, sprays for hops, etc., and was also used for vulcanizing rubber, for pharmaceutical purposes and for bleaching.

As it became necessary to arrange for supplies of sulphur for the various Government contact plants, sulphur was imported by the Ministry and issued to Government factories. At the close of 1916 it became evident that there was every likelihood of a world shortage of sulphur and particularly of an excessive demand on the reserves available from Sicily. Accordingly, on 18 December, 1916, a meeting was held at the Explosives Supply Department at which representatives of the Ministry, the India Office, the Colonial Office, the Board of Trade, and the Board of Agriculture were present. At this meeting it was stated that the requirements of the Explosives Supply Department for 1917 would be roughly 120,000 tons, and the requirements for British trade purposes 20,000 tons. It was suggested that the department should be the sole importing and distributing agency in respect of sulphur.

The Italian Government had granted an allotment of sulphur for Great Britain and her colonies, requesting that His Majesty's Government should purchase the quantity allotted to Great Britain direct from themselves and be responsible for its distribution. The

[1] Based chiefly on 74/HES/232.

following steps were accordingly taken by the Explosives Supply Department:—The export of sulphur and sulphur products was stopped, except in the case of very small quantities for medical purposes. The applications for a supply of sulphur were examined and allotments were made for use in home trade, but permits were refused when the sulphur was wanted for export. The Italian imports were augmented by the purchase of 30,000 tons in America, and India and the colonies were urged to procure their supplies from Japan or the United States of America. Two available resources to meet any remaining deficit were pointed out, one being the stock of sulphur already in the country and the other the home produced or "recovered" sulphur produced by two well-known firms, and mainly used for industrial purposes other than acid manufacture. It was therefore suggested that it might be possible to remove the embargo on the export of sulphur products.

On 2 February, 1917, an inter-departmental Sulphur Committee was appointed. It approved the action taken by the Explosives Supply Department, and agreed that the embargo placed on the export of sulphur products (sheep-dips, etc.) should be removed, provided applications for permits to export sulphur products were submitted by the War Trade Department to the Ministry. In May, 1917, a circular was issued announcing, on behalf of the Minister of Munitions, the steps which had been taken and fixing prices for flowers of sulphur, roll brimstone and thirds. "Recovered" sulphur could be purchased in the ordinary way of business from home producers. In September, 1918, a further notice was issued revising the scale of prices of sulphur supplied by the Sulphur Committee on account of increasing costs, and stating that the other terms and conditions of supply would remain unchanged.

During 1917, 52,600 tons of sulphur were imported by the Government and during 1918, 67,800 tons. The amounts used for acid manufacture during these two years were 44,900 tons and 34,200 tons respectively.

(*c*) Spent Oxide.[1]

The hydrated oxide of iron used in gas-works as a purifier becomes in time too heavily charged with sulphur for further use, and is then utilised by acid manufacturers as a raw material for the manufacture of sulphuric acid—its sulphur content being approximately 50 per cent. The quantity of this material available is of course a limited one, and the maximum annual consumption during the war, *i.e.*, in 1916, was 127,000 tons.

Owing to the increased cost of imported pyrites, due to higher freightage and insurance charges, the value of spent oxide rose considerably, and during 1916 the available stocks were considerably reduced, so that there was a danger of a serious shortage for those works which were dependent upon supplies of spent oxide for their

[1] X 240.

production of acid. In 1917, an Advisory Committee of the principal spent oxide dealers and users was, therefore, appointed, and they were asked to control prices and keep them at a reasonable figure. This they did, the Department keeping in touch with them and obtaining data regarding stocks throughout the country, and also touching receipts and consumption.

(*d*) Chile Nitrate.[1]

Throughout the war, nitrate of soda was a fundamental raw material of the explosives industry. It was essential for the production of nitric acid by the standard retort process, and it also played a part in the production of sulphuric acid by the chamber process, the amount imported annually into Great Britain for this latter purpose, before the war, being estimated as about 18,000 tons.

Possible methods for the manufacture of nitric acid, other than by the use of sodium nitrate, were by the fixation of the nitrogen of the atmosphere or by the oxidation of ammonia obtained otherwise than from the atmosphere. As there were no established methods of fixing nitrogen from the atmosphere in operation in this country by which nitrates and nitrogen products could be secured on a large scale, and as the ammonia oxidation process was undeveloped, Great Britain was compelled throughout the war to rely upon the importation of sodium nitrate from Chile. These supplies were supplemented by small quantities of synthetic nitrate from Norway.

The increased output of chamber acid during the war necessarily called for increased supplies of nitrate to provide the oxides of nitrogen required in the leaden chamber process ; but before the close of the war the ammonia oxidation process was applied to the manufacture of chamber acid, inexpensive " converters " being designed and introduced by the Munitions Inventions Department to supply the necessary oxides of nitrogen.

Before the war, Chile nitrate of soda had its widest use as a fertiliser, about 75,000 tons out of the 112,300 tons used in this country per annum being employed in agriculture. The imperative necessity for economising it as the difficulties of importation increased led, however, to its almost total diversion from agriculture to explosives in all belligerent countries. The average annual pre-war import of 95 per cent. (commercial) nitrate of soda was 131,000 tons, of which 18,700 tons were re-exported. Of the remainder, besides that used in agriculture and the manufacture of sulphuric acid, about 12,500 tons were used as a source of nitric acid, and about 4,300 tons in the manufacture of potassium nitrate.

For the purpose of supplying the needs of Government explosives factories and of establishing substantial reserves, the Explosives Supply Department early took steps to ascertain the stocks of nitrate of soda in the United Kingdom and to build up reserves. By contracts in 1915, the Department purchased over 300,000 tons in Chile through

[1] Hist. Rec./H/1512/1.

the agency of Messrs. Anthony Gibbs & Sons and other firms, and made arrangements with the Norsk Hydro-Elektrisk Kvaelstof-aktieselskab to take their whole output of synthetic nitrate of soda less a maximum of 1,500 tons annually, which the contractors were to retain for consumption in Norway, Sweden and Finland. At the end of July, 1915, about 72,000 tons of nitrate had been delivered and stored in the United Kingdom. This Government stock of nitrate was looked upon as a reserve to be used in case of stoppage of regular supplies to the trade, through which the needs of such contractors as were not assisted by the Government continued to be met. In August, 1915, the trade nitrate stocks in the country were estimated to be between 75,000 and 80,000 tons, and the average annual rate of consumption at from 150,000 to 200,000 tons.

As the munitions programme enlarged and difficulties of securing nitrate increased, it became clear that the agricultural demands for nitrate, although pressing, must give way to the explosives demand, and towards the end of 1916, 35,500 tons, which had been purchased by the Board of Agriculture and Fisheries, were transferred to the Ministry. By the end of December, 1916, a reserve exceeding 325,000 tons of nitrate of soda had been accumulated in this country.

In view of the largely increased output of explosives, arrangements were made with the Shipping Controller early in 1917 for the delivery in this country of 50,000 tons per month, beginning in May. Owing to the pressing need for other imports, however, this quantity had to be reduced to 40,000 tons per month, and it was eventually found to be impossible to allocate even this amount of tonnage. From the middle of the year the nitrate situation began to assume a serious aspect and every effort was directed to accumulating a reserve of 500,000 tons in Europe as rapidly as possible. From May, 1917, to December, 1917, the actual arrivals in this country averaged only 22,400 tons monthly in addition to which about 42,000 tons were diverted to France in the autumn of 1917.

These much reduced receipts fell far short of the actual average monthly issues of nitrate during 1917, which were 36,000 tons, representing actual consumption and stocks in course of consumption at factories. A heavy demand upon the accumulated reserves was thus occasioned, and at the end of the year they stood at only 115,000 tons—a fall during the year of 210,000 tons or 65 per cent.

The outlook at the beginning of 1918 was a very serious one for this country, and the general European situation gave equal concern. In spite of the diversion of cargoes from England and America in 1917, France and Italy held between them less than 37,000 tons, and it was obvious that their stocks would shortly be exhausted. At the same time America held barely more than a working stock.

The gravity of the nitrate situation was due to several causes. The annual demand for nitrate of soda in this country rose steadily until it approached nearly five times the pre-war consumption, while the steady increase of freight rates from Chile resulted in there being few private cargoes so that manufacturers soon became chiefly dependent

on the Government's reserve stock. The submarine campaign, which began in 1916, created a general shortage of tonnage and as time went on the transport question became acute, France and Italy often being unable to find the necessary shipping to transport their nitrate supplies, so that the burden fell on Britain or the United States.

The position in Chile also became very difficult, especially during the late summer of 1917. Shortage of fuel, labour troubles, etc., threatened to diminish the output of nitrate so that companies generally were unwilling to sell for forward delivery, while competition for such nitrate as was available rapidly forced up the already high prices. During the summer the political situation was so uncertain that it was necessary to accumulate certain reserves at ports in case railways should be cut.

It was considered imperative to stop the existing competition in the Chilian market between the various European Governments, the American Government and private individuals in America. A project was, accordingly, discussed in September, 1917, for the formation of a Nitrate of Soda Purchasing Executive to consist of representatives of Great Britain, France, Italy, the United States and Russia, and in November this Executive came into being.

On 18 October, 1917, as a preliminary to the formation of this Executive, a Nitrate of Soda Order, to be administered by the Explosives Supply Department, was issued in this country, bringing the material under Defence of the Realm Regulation 30A.[1] Subsequently, the Ministry came to an arrangement with the War Trade Department by which the issue of priority certificates and licences for the export to Chile of spare parts in connection with nitrate plants might be expedited through the Explosives Supply Department.

The function of the Nitrate of Soda Executive was to control purchases and to allocate the supplies from Chile. Control was secured by pooling all purchases and restricting private buying through other channels, and, in arranging distribution, preference was given to requirements for explosives manufacture. Negotiations were also undertaken to prevent any further rise in market prices, and arrangements were at once made to relieve the troubles of nitrate producers in Chile by securing for them adequate supplies of oil and coal, and other stores, the United States agreeing to supply 600,000 tons of oil per annum and the British Government 300,000 tons of coal.

One of the chief difficulties with which the Executive had to contend was the lack of the necessary shipping, particularly in the case of France and Italy. The needs of these two countries were so imperative that it was necessary to divert cargoes to them from this country during the early months of 1918, but arrangements as to doing so were complicated by questions of finance, owing principally to difficulties as to rates of exchange.

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[1] Appendix XV., No. 5.

Towards the end of March the United States, becoming alarmed at the low reserve stocks of nitrate for Allied use, made an effort to build up her reserves and urged Great Britain to take similar steps. At that time more tonnage was not available for the purpose, but by July the shipping position had substantially improved; home stocks of nitrate stood at 142,000 tons and there were 109,000 tons afloat. The diversion of 20,000 tons to France was therefore approved.

Throughout 1918, the negotiations with Chile were of a very difficult character; the extent of the British interests, which formed 36 per cent. of the nitrate trade, as opposed to 8 per cent. held by Germans, had always to be kept in mind. Owing to increased cost of production, notably the increased price of oil and the rise in exchange, producers had reached a point where they were unwilling to sell at the price at which the Executive were prepared to buy. In June, 1918, the Chilian Minister in London made a proposal that his Government, on behalf of the majority of producers, should sell 680,000 tons of nitrate to the Executive. Great Britain, meanwhile, in order to relieve the shipping position, had been endeavouring since the beginning of the year to drive a counter bargain with Chile, and by putting forward projects for the erection of synthetic nitrogen factories in England, had sought to bring pressure on her to release German shipping. In October, the Minister of Munitions, on behalf of the Executive, completed the negotiations for the purchase from the Chilian Government of 680,000 tons of nitrate to meet the requirements of the Allies till the end of the year, the Chilian Government agreeing to supply certain transports when they became available. At the date of the Armistice, the Allies had in stock 1,460,000 tons of nitrate, of which the British share was about 400,000 tons.

During the war period, the price of nitrate rose considerably. The average price for the three pre-war years in England was £10 13s. 9d. per ton. This rose approximately to £12 13s. in 1915, to £17 12s. 6d. in 1916, to £23 10s. in the first half of 1917, and to £27 in the latter half of that year, the last figure representing an increase of about 150 per cent. on the pre-war average.

The Nitrate Executive, to which Mr. Herbert Gibbs was appointed Director of Purchases—a duty which he carried out for the Allies for a financing commission of $\frac{1}{2}$ per cent.—began buying in January, 1918. The price of all nitrate, f.a.s. a South American port, was the same to all Governments, all charges for loading, freights, insurance, and transport from the time the nitrate was delivered f.a.s. a South American port, being for the account of the Government to whom it was allocated, that Government being responsible for its transportation and for the financing of the purchases.

The control of nitrate of soda was suspended on 15 May, 1919.

(*e*) Projects for the Synthetic Production of Nitric Acid and Nitrates.[1]

Before the war, the Central Powers were the largest purchasers of Chile nitrate, taking, in 1913, 840,000 tons as against 589,000 tons imported by the United States, and 128,000 tons by the United Kingdom. Yet though entirely cut off by the blockade from supplies of Chile nitrate, they continued vigorously to carry on the war. It was obvious that they were enabled to do so by having developed processes for the fixation of atmospheric nitrogen, some of which had been established before the war.

The importance of ascertaining as soon as possible to what extent and how quickly nitrogen products such as nitrates, nitric acid and ammonia could be manufactured in this country was emphasised by this consideration, and still more by the development in February, 1916, of the submarine campaign, which was a grave menace to the supplies of nitrates from overseas, and resulted in its becoming necessary to divert nitrate from agriculture to munitions at a time when in order to increase food supplies increased quantities of fertilisers were required.

The chief obstacle in this country to the development of schemes for the synthetic production of nitric acid and nitrates was the lack of natural water power, since such projects involved the use of a considerable amount of electric power which could not be cheaply produced in Great Britain.

In February, 1916, Lord Moulton had pronounced against this country's having immediate recourse to the manufacture of nitric acid from the nitrogen of the atmosphere by means of the well-known process of the electric arc, in view of the very large power plant that would be required; but in June, 1916, the Nitrogen Products Committee was appointed to consider future possibilities. The Committee began an exhaustive examination of the nitrogen problem in relation to the military, agricultural and industrial requirements of the United Kingdom and other parts of the British Empire, and developed an important programme of chemical research.

In February, 1917, the Committee presented an interim report which recommended practical schemes for the synthetic production in this country of nitrogen products urgently needed for munitions. The Committee also urged the importance of increasing the output of by-product ammonia for munitions and agriculture. A brief review was given of methods of obtaining nitrogen products by the ammonia oxidation process, the cyanamide process, the Haber (synthetic ammonia) process and the electric arc process, all of which would require the installation of plant on an extensive scale if they were to be established in Great Britain.

By the ammonia oxidation process, ammonia derived from any source is oxidised to nitric acid. The acid may be concentrated

[1] Based chiefly on Hist. Rec./R/700/26, H/1512/1, R/1512/8.

or may be combined with additional ammonia to produce ammonium nitrate. It was by the oxidation of ammonia that Germany was obtaining most of her nitric acid.

The calcium cyanamide process, which at that time was well established in Scandinavia and at the Niagara Falls, involves the production in electric furnaces of calcium carbide, which is afterwards caused to react with nitrogen gas to produce calcium cyanamide. Cyanamide in the commercial form of nitrolim is, under certain conditions, a valuable fertiliser. Upon treatment with steam, cyanamide yields ammonia which can be converted into ammonium sulphate (also a valuable fertiliser), or into ammonium nitrate, or oxidised into nitric acid by the ammonia oxidation process.

It was strongly recommended that, so far as the conditions of labour permitted, the ammonia oxidation and the cyanamide processes should be established forthwith in this country.

By the Haber (synthetic ammonia) process ammonia is produced by the direct combination of pure nitrogen and pure hydrogen at high pressures (about 200 atmospheres) under the influence of catalytic agents. The process was developed to a very great extent in Germany during the war. As little information regarding it was known outside Germany, the Nitrogen Products Committee were carrying out experimental investigations on this process, and recommended that a semi-industrial unit for the synthetic production of ammonia by the Haber process should be erected at an early date.

In the arc process the direct combination of atmospheric oxygen and nitrogen is effected by means of the electric arc, the primary product being weak nitric acid, which can be either concentrated or converted into ammonium nitrate. The Committee, on grounds similar to those on which Lord Moulton had rejected it, did not recommend the adoption of this process as a war measure.

On 15 March, 1917, the Minister gave his decisions on the recommendations made by the Nitrogen Products Committee and appointed an Executive Committee to supervise the necessary action. As a result of these decisions the following action was taken :—

(1) The by-product ammonia position was examined by the Executive Committee and the task of conserving and increasing the output of by-product ammonia was then entrusted to the Explosives Supply Department.

(2) A conference with manufacturers on the ammonia oxidation process was held on 23 March, 1917, and the results of research work done by the Munitions Inventions Department were placed at their disposal, together with designs of ammonia oxidation converters. The use of ammonia oxidation converters in connection with sulphuric acid chamber plants was urged in a pamphlet issued in December, 1917, by the Munitions Inventions Department, and during 1918 some sulphuric acid manufacturers installed these and so saved nitrate of soda. The value of the ammonia oxidation for war purposes, however, lay in the fact that it could be used for the production of ammonium nitrate, the consumption of which in service explosives was growing

with great rapidity. An ammonia oxidation plant installed by the Nitrogen Products and Carbide Company, and worked on the system devised by Professor Ostwald, had just come into operation at Dagenham in February, 1917, but its working did not prove very satisfactory. By August, 1917, as an outcome of the Government research work on ammonia oxidation, arrangements were made for the erection in London of a full-scale trial unit having an output of 300 tons of strong nitric acid per annum, but at this juncture the work of establishing the process on a commercial scale for the manufacture of nitric acid and ammonium nitrate was handed over to the Explosives Department at their request.

(3) In the meantime the Executive Committee had had under consideration the question of the production of calcium cyanamide. In July, 1917, they reported to the Minister that the schemes involving private enterprise were not likely adequately to fulfil the ends in view, and recommended the erection of a Government factory and the adoption of a particular process—that operated by the Stockholm Superfosfat Company.

(4) The progress of research work on the Haber process resulted in a semi-technical unit being brought into operation in October, 1917, and it was hoped that the results obtained from this large experimental plant would settle the remaining problems as to chemical engineering details of a full-size trial unit, the erection of which the Minister had authorised in March.

In October, 1917, the Explosives Department submitted to the Minister a memorandum by Mr. K. B. Quinan recommending the erection of a Government factory for the manufacture of synthetic nitrogen compounds by means of the Haber and ammonia oxidation processes. It became a question, therefore, whether the cyanamide process or the Haber process was to be established in order to relieve, by the fixation of atmospheric nitrogen, the critical situation that had developed through the tremendous drain on the country's reserves of Chile nitrate, and, in particular, to provide for the supply of increased quantities of ammonium nitrate to meet extensions in the use of amatol as an explosive. An objection to the former process was its large power requirements, but against the latter could be urged the necessarily experimental nature of the process as a commercial operation, and its requirement, on the scale on which it was proposed to establish it, of the production of hydrogen at a low price on a scale hitherto unknown in this country, and of a high standard of purity difficult of attainment.

In January, 1918, Treasury sanction was sought for an expenditure of £4,000,000 for the erection of a factory to produce 50,000 tons of nitric acid per annum by the fixation of atmospheric nitrogen. The Haber and cyanamide processes were to be utilised to obtain the ammonia, part of which was to be oxidised by the catalytic process, the nitric acid so formed to be neutralised by the other part of the ammonia, to yield ammonium nitrate (60,000 tons). A change in the scheme was made a little later, when the proposal to make use

of the cyanamide process was dropped, as it was agreed that the necessary plant would take longer to instal than that required for the Haber process.

There was some delay in the granting of Treasury sanction, but the nitrate of soda position was rapidly growing more serious, and, following on the decision of the Treasury Committee on 22 March, 1918, that the scheme should be undertaken by Mr. Quinan with the utmost possible despatch, sanction was finally given for the necessary expenditure.

The site finally selected for the factory covered 271 acres at Billingham, near Middlesbrough. In July, 1918, it was estimated that the ammonium nitrate (ammonia oxidation) section of the factory would start producing in the New Year, and the Haber or ammonia section in June, 1919. Progress was, however, hampered by low priority and the difficulty of getting labour; and at the beginning of October, 1918 (six months after Treasury sanction had been obtained), Mr. Quinan recommended that the scheme should be abandoned as, under existing circumstances, there was no prospect of reaching production in the time estimated, so that the project could no longer be regarded as a war measure, and as a post-war measure the scheme would require much alteration. The Explosives Supply Department was then concentrating attention on the immediate need for poison gas production on a large scale, and was not in a position to embark on these alterations.

In view of the then more favourable nitrate situation, and of the overwhelming claims of poison gas manufacture, Lord Moulton was agreeable to the suspension of the scheme. The question was still under consideration when the Armistice was declared, and, shortly after this, work on the Billingham factory was suspended. Later, it was decided that further development should be left to private enterprise, and the Billingham factory was accordingly sold to Messrs. Brunner Mond & Company.

V. Summary and Tables.

The total production of nitric acid (expressed as 100 per cent. acid) during successive years of the war was 16,800 tons during the year 1914, 85,000 tons in 1915, 172,500 tons in 1916, 237,000 tons in 1917, and 158,000 tons in 1918, whereas previous to the war the average annual production was about 14,000 tons. Large quantities of sulphuric acid were used in its production, the amount of sulphuric acid used to nitric acid made being 1·50 in 1916, though this factor was reduced to 1·47 in 1917, and to 1·42 in 1918.

The production and main uses of oleum and of sulphuric acid generally (including oleum) for the years 1916, 1917 and 1918, are shown in the two following tables. It should be noted that in the first table, oleum produced from feed acid is included; whereas in the second, the sulphuric acid production by contact plant is a nett figure, *i.e.*, it represents the sulphuric acid actually produced from the pyrites or sulphur exclusive of any feed acid introduced into the plant during manufacture.

OLEUM (20% FREE SO_3).

	1916. Tons.	1917. Tons.	1918. Tons.
Production	183,000	367,000	288,000
Imports	5,500	1,500	—
Total	188,500	368,500	288,000
Consumption—			
For Explosives	179,000	352,000	276,500
For Trade	6,500	11,000	18,000
For Export	—	—	1,000
Total	185,500	363,000	295,500
Stocks on 31st December	11,000	16,500	9,000

SULPHURIC ACID IN TERMS OF 100% H_2SO_4

	1916. Tons.	1917. Tons.	1918. Tons.
Production by Contact Plant—			
Government Factories	42,177	138,859	112,178
Trade	63,496	82,227	54,465
Total	105,673	221,086	166,643
Imports	5,716	1,790	—
Production in Chamber Acid Plant	1,208,275	1,160,789	964,158
Total Available	1,319,664	1,383,665	1,130,801
Quantity of Chamber Acid used to manufacture Concentrated Acid (10 per cent. loss allowed in process)	371,710	375,517	204,814
Concentrated Acid Production (from Chamber Acid Plant)	334,540	337,965	184,333
Consumption[1]—			
For Explosives	258,540	274,689	130,114
For Trade	76,000	63,276	54,219

Owing to economies effected in the production of explosives, the sulphuric acid requirements were considerably reduced per ton of explosive. The following table shows the overall consumption of sulphuric acid, including that required to make the necessary nitric acid per ton of explosive manufactured for successive periods during the years 1916, 1917 and 1918. Much of the reduction shown was due to the recovery and re-use of waste acid which was arranged for by the

[1] A sharp division between Explosives and Trade is extremely difficult, but the figures given are substantially correct.

construction and extension during 1916 of the necessary recovery plant, but a part of the saving was due to increased efficiency in other directions. Since the figures include sulphuric acid used for the manufacture of nitric acid except in the case of phenol production, any improvement in the efficiency of nitric acid plant is reflected in them.

CONSUMPTION OF SULPHURIC ACID (100 %) PER LB. OF EXPLOSIVES MADE (ACID EXPRESSED AS 100 % H_2SO_4).

PERIOD.	T.N.T.	PICRIC ACID FROM PHENOL.		PICRIC ACID FROM D.N.P.	SYNTHETIC PHENOL.	PROPELLANTS.
	Sulphuric Acid, including Oleum and that used for Nitric Acid, deducting acid reconcentrated.	Sulphuric Acid for Sulphonation, deducting acid reconcentrated.	Sulphuric Acid, including that for Sulphonation and Nitric Acid, deducting acid reconcentrated.	Sulphuric Acid, including that for Nitration and Nitric Acid deducting acid reconcentrated.	Sulphuric Acid, including Oleum.	Sulphuric Acid, including Oleum and that used for Nitric Acid, deducting acid reconcentrated.
1916.						
March—June ..	4·36	1·93	4·75	2·90	4·55	No data available
July—September ..	3·13	1·81	4·44	2·40	3·99	2·29
October—December	3·04	1·79	4·39	2·67	3·49	2·14
1917.						
January—March ..	2·75	1·50	4·18	2·58	3·35	1·94
April—June	2·23	1·46	4·01	2·0	3·21	1·71
July—September ..	2·24	1·34	3·86	2·14	3·08	1·70
October—December ..	2·08	1·26	3·66	1·96	3·12	1·64
1918.						
January—March ..	2·26	·78	3·10	2·44	2·86	1·51
April—June	1·96	·58	2·64	1·85	2·30	1·45
July—November ..	1·78	·57	2·66	—	2·42	1·55

The production of hydrochloric acid remained fairly constant throughout 1916, 1917 and 1918, the greatest annual output, *i.e.*, 288,991 tons being reached in 1917.

CHAPTER IV.

SOLVENTS, GLYCERINE AND COTTON-WASTE.[1]

I. Acetone and the By-Products of Wood-Distillation.

(*a*) Dependence upon Overseas Supplies.

At the outbreak of war, the solvent used in cordite manufacture was acetone. It was produced almost entirely by the destructive distillation of wood, and was imported from the great timber-growing countries, the United States of America, Canada, and Austria. Under normal conditions, the prices ruling for this material and the other products of wood-distillation were very low, and private British firms could not compete successfully with foreign makers. A number of small private factories existed, but their plant was very antiquated. In 1913, the Office of Forests and Woods had erected a factory at Coleford, in the Forest of Dean, where the plant was laid out along modern German lines for carbonising waste hard-wood.

Hence, the country was practically dependent upon imported acetone, and a national stock of some 3,200 tons[2] had been accumulated at the Royal Gunpowder Factory, mainly on behalf of the Admiralty. This quantity soon appeared insufficient for the growing demand for cordite.

(*b*) State Purchases for the Trade.

By the spring of 1915, the position in the American acetone market had become extremely delicate. British cordite firms were competing with each other and with the agents for the Allies. Prices were driven up and certain American contractors threatened to default on their orders. The increased demands of the previous October had led to the erection of acetone plants in the Eastern States by firms who relied for their raw material, acetate of lime, upon numerous small makers. These were threatening to close down, as a mild winter, a reduction in requirements for charcoal iron, and greatly inflated production had deprived them of the market for their main product, charcoal.[3] Moreover, as a natural consequence of the abnormal increase in wood-distillation, the price of the by-products in America tended to decrease and makers of acetate of lime sought to refund themselves by advancing the price of that material. Under these circumstances, American acetone producers stipulated for an advance in price upon their existing contracts with the British Government.

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[1] Based, where no other reference is given, upon Hist. Rec./H/1530/6.

[2] It was actually 3,200 tons in August, 1914. It had been estimated at 3,300 tons, of which 3,000 were for the Navy.

[3] Morgan Cables, N.Y. 2829. (A complete set of these cables is filed in the Archives Registry).

In one instance, it proved impossible to recover liquidated damages from a contractor, although these had become enforceable under the usual contract terms. Negotiation was the more difficult, since acetone producers in the States were working in close combination, and Canadian output was insufficient for the requirement.[1]

Competition between British cordite makers was eliminated early in 1915, when Nobel's Explosives Company agreed to purchase acetone for the explosives trade, throughout the remainder of the year, except for two firms already covered. The War Office continued to buy acetone for the Royal Gunpowder Factory during the same period, acting through Nobel's agent (Messrs. C. Tennant & Sons) to avoid confusion. Competition between the Government and the trade was further avoided by an undertaking made by the War Office in April, 1915, to keep all cordite makers supplied with acetone during the year 1916 on condition that they refrained from entering the market on their own account.[2] The supplies for the current year then seemed fully covered. Negotiations for the whole of the American production during 1916 were instituted through Messrs. J. P. Morgan, the War Office agent. This was only secured by accepting a general advance in the price of acetone delivered after July, 1915, under existing acetone contracts, so as to cover the rise in the cost of acetate of lime. In order to avoid disturbing the price for cordite, the War Office undertook to refund to explosives makers the difference between this price and the rates at which they had already placed their orders for acetone during the next half-year. Two American firms, outside the acetone combine, were also given assisted contracts, capital being advanced for laying down plant and an undertaking given, in one instance, to place continuation orders at rates based upon the cost of acetate of lime.[3]

When all the overseas supplies immediately available had thus been purchased, the deliveries anticipated still remained considerably below the requirements for 1916. The position was met in part by the adoption of a new form of cordite (R.D.B.) manufactured with the solvent ether-alcohol instead of acetone.[4] Extensions to British acetone plant which was dependent upon wood-distillation proved disappointing owing to difficulty in procuring timber supplies. The plantat Coleford, in the Forest of Dean, was capable of making 100 tons yearly[5] and was extended to make 400 tons of acetone from acetate of lime to be produced at factories which were erected at Dundee, Bideford and elsewhere. In April, 1915, Messrs. Kynoch agreed to manufacture, at Kynochtown, 42 tons of acetone monthly from acetate of lime produced at their factory at Longparish, co. Hampshire. It was necessary to supplement the output from Longparish with imported acetate of lime and imported acetate was used also by the United Alkali Company, who manufac-

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[1] HIST. REC./H/1500/5/2.
[2] HIST. REC./H/1530/6, pp. 10–11 ; HIST. REC./R/245/1.
[3] HIST. REC./H/1530/6, pp. 71–75 ; HIST. REC./H/1500/5/2.
[4] See Vol. X., Part IV.
[5] A_7 Return of Explosives and Constituents ordered by the War Office to 7 June, 1915 (HIST.REC./R/1000/61).

tured four tons of acetone weekly at Widnes. The cost of imported acetate was reflected in the very high prices charged under this last contract. Moreover, the importation of acetate merely reduced the quantity of acetone available from the United States and increased the tonnage used in obtaining acetone.

(c) Development of New Manufacturing Methods in Great Britain.

It remained to attempt manufacture by some other process than wood-distillation. At home, plant for the production of acetone and butyl-alcohol by fermenting the starch content of potatoes existed at King's Lynn, where the Synthetic Products Company had converted an oil-cake factory for this purpose in 1912. Loans were made to the firm towards extending the factory to produce seven tons of acetone weekly, and in April, 1915, the company undertook to supply this material at a price based on the cost of potatoes. The acetone produced did not reach the specification standard and needed re-distillation. In view of the unsatisfactory results and the financial position of the company, the factory was taken over under the Defence of the Realm Regulations, in March, 1916, and controlled directly by the Propellants Branch of the Explosives Supply Department. In June, 1916, a new method of fermentation from maize was adopted at the factory with far more satisfactory results than had previously been obtained. This was the Weizmann process, suggested by Dr. Weizmann, of Manchester University, in April, 1915. Experimental work was first conducted at the Three Mills Distillery, Bromley, under a grant sanctioned by the Treasury Emergency Standing Committee on 30 April, 1915, and later research was carried on at the Lister Institute at the joint expense of the Admiralty and the Ministry of Munitions. Plant was erected at the Royal Naval Cordite Factory and later by the Indian Government at Nazik. In February, 1916,[1] it was decided that manufacture of acetone by the Weizmann process should be undertaken on a considerable scale, reliance being placed upon the sale of the by-product butyl-alcohol to make manufacture by this process a commercial success. Since it was considered that there would be insufficient freight to import maize both for this purpose and for the manufacture of potable spirit, it was decided to adapt the plant of some of the patent still distilleries for making acetone. This decision was communicated to representatives of the distillery trade by the Minister of Munitions and the President of the Board of Trade on 16 February, 1916, and work upon the conversion of the first of the six distilleries which were ultimately chosen as the most suitable began in the following March. The distillers undertook to produce acetone for the period of the war and six months after. The cost of the installations was borne by the State, and the Minister undertook to pay certain specified items of expenditure, together with a sum equivalent to 1½d. per gallon per year of proof alcohol produced by each distillery previous to notice of the Minister's

[1] Hist. Rec./R/1510/1.

intention to convert it for acetone manufacture. This sum was in satisfaction of working expenses, overhead expenses and rent. In addition, the Minister undertook to pay in respect of interest and profits another 1d. per gallon on the estimated yearly capacity of the distillery and 3d. per gallon of pure acetone produced. All products and by-products were to be the property of the Minister, who undertook to refund the main items expended on manufacture, viz., on materials, power, wages and maintenance. Difficulty was experienced in obtaining the special plant and the labour needed for converting the distilleries, and only two out of the six actually produced. The operation of these converted distilleries was more difficult than production by the same methods with newly-erected plant, particularly in regard to economy of grain. Difficulty was also experienced in finding a market for the butyl alcohol.[1] More important still was the growing shortage of freight, which threatened to cut off the supplies of maize. The productive capacity of the two distilleries making acetone in February, 1917, was 228 tons monthly; their consumption of maize was 4,560 tons. Further purchases of American acetone and the general adoption of the new form of cordite, R.D.B., had considerably reduced the acetone requirement in the meantime. Accordingly, on 22 February, 1917, the Minister gave instructions for the cessation of acetone production at distilleries.[2] Some part of the plant which had been installed was purchased by the distillers and the remainder was dismantled and sold.

In addition to these attempts to manufacture acetone from maize, a catalytic process for its production from alcohol was worked out by Messrs. J. Crosfield & Sons at the suggestion of Professor Perkin.[3] Alcohol was converted into aldehyde, aldehyde into acetic acid and acetic acid into acetone. Under agreement with the Propellants Branch, the firm erected plant for an estimated output of 100 tons monthly. It was complete in March, 1917, but considerable difficulty was experienced in rectifying the acetone up to Government standard. The output had not passed beyond the experimental stage of some four tons weekly when, after a three months' suspension of work caused by an accident in August, 1917, the process was stopped at the second stage as a means of increasing acetic acid supplies.

During the year 1917 a scheme was also set on foot for making acetone from horse-chestnuts. Factory experiments were carried out with a view to substituting chestnuts for maize at the King's Lynn factory. During the autumn about 3,000 tons of chestnuts were collected by voluntary efforts, mainly on the part of school-children, the quantity being restricted mainly by transport difficulties. Output, which began at the King's Lynn factory in April, 1918, was also hampered by the poor quality of the material; but these practical difficulties were satisfactorily overcome shortly before the factory was closed down in July, 1918.[4]

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[1] HIST. REC./H/1500/5/1.
[2] HIST. REC./R/1510/1/12.
[3] HIST. REC./H/1530/18.
[4] HIST. REC./H/1530/15.

(*d*) Stimulation of New Processes in America.

In order to economise timber, new processes were also adopted both in the United States of America and in Canada. In June, 1915, the Hercules Powder Company agreed to supply over 1916 certain quantities of cordite made from acetone, which should be derived from some source other than wood distillation, as well as certain quantities of acetone to be produced by the same method.[1] For this purpose, the firm employed a sub-contractor, the United States Industrial Alcohol Company, to erect and operate plant for making acetone by a vinegar process. The yield was poor and deliveries fell into arrears. A direct contract was placed with the Industrial Alcohol Company and improvements were effected upon advice given by an expert on vinegar production lent by Messrs. Crosse & Blackwell. Deliveries from this source terminated in June, 1917, when the plant was used for commercial purposes.

A far more successful venture was the conversion of two adjacent distilleries in Toronto, which formerly produced alcohol from grain and molasses, into the British Acetone Toronto factory for making acetone by the Weizmann process.[2] Early in 1916 the directors of these distilleries placed their plant at the Minister's disposal for the duration of the war and one of them (Colonel Gooderham) acted as manager. The works were operated at Toronto and Terre Haute, and 2,563 tons of acetone were produced between January, 1917, and November 1918.

A second Canadian project was the catalytic manufacture of acetone from calcium carbide. The process was worked out at the McGill University, Montreal, and upon experimental plant erected by the Shawinigan Water and Power Company. This company supplied carbide at cost price from its existing plant to the Canada Electro Products Company, which was formed for the purpose, and undertook, in April, 1916, to deliver 3,600 tons of acetone at cost, plus 12½ per cent. profit, plus a fixed sum per lb. to cover amortisation. During May, 1917, when the practical difficulties of starting up a new method of production had been overcome, 200 tons of acetone were delivered. Towards the end of the year this factory and Messrs. Crosfield's works turned over to the production of acetic acid, for which an increased demand had arisen.

(*e*) Growth in the Importance of By-Products.

Control over all dealings in acetone and acetate of lime was taken under Defence of the Realm Regulation 30A, in February, 1916. Sustained purchases of acetone in America, supplemented by the ventures described above, sufficed to meet the acetone requirements for 1917. These, moreover, had been greatly reduced by the gradual substitution of cordite R.D.B. for cordite M.D. In the meantime other products of wood-distillation were gaining in importance. The uses of these were developed and extended considerably for the

[1] 95/Firms H/3. [2] Hist. Rec./H/1530/16.

purposes of the war. The main by-product, charcoal, had an important application in the manufacture of charcoal iron. Methyl-alcohol, used normally as a denaturant in the production of methylated and mineralised spirit, was also employed in the production of formaldehyde, and the valuable medicinal substance, guiacol, was extracted from tar residues. Acetate of lime is the raw material for acetic acid as well as for acetone, and the demand for acetic acid grew rapidly with the use of the standard lachrymator, ethyliodoacetate, adopted by the British forces in 1915. Later, with the development of the aircraft programme in the summer of 1917, the demand for acetone itself as well as for glacial and high-strength acetic acid and methyl-ethyl-ketone, as solvents in the preparation of dope, increased in importance.[1]

The entry of America into the war in 1917 gave rise to a considerable amount of speculation in acetate of lime and glacial and acetic acid. Acetic acid for the manufacture of ethyliodoacetate was being provided to makers of that liquid as free issues by the Trench Warfare Supply Department, which was concerned with chemical warfare supplies. The acid so issued had been made from imported acetate of lime by the single British firm which normally produced pure acetic acid.[2] During the summer of 1917 the position in regard to solvents for aeroplane dope also became highly critical owing to the need for a non-inflammable dope, the impracticability of using "Westresol" dopes, which had poisonous effects on the workers, and the failure of the British Cellulose Company's scheme for producing synthetic acetic acid. This company purchased American supplies of acetic acid through agents whose activities tended to raise the price of wood-distillation products generally.[3] It was accordingly agreed in September, 1917, that the Trench Warfare Supply Department should purchase from Canada and the United States all the glacial and high strength acetic acid available for both poison gas and aeroplane dope production, and should control sale and purchase in the United Kingdom in order to stop speculation. For this purpose, an Order dated 21 September, 1917, brought strengths of 80 per cent. and over under Defence of the Realm Regulation 30A, and a second Order, dated 1 October, extended the operation of the regulation to all strengths.[4] In December, 1917, the administration of control was transferred to the Propellants Branch of the Explosives Supply Department which was already regulating dealings in other wood-distillation products, and was about to provide from the synthetic acetone plant installed by Messrs. Crosfield and the Canada Electro Products Company practically the whole supply of acetic acid both for Government purposes and for the trade.

The rationing of consumers of acetic acid was a matter of considerable difficulty. It was needed in various strengths by the textile, colours, and chemical industries and for edible and medicinal purposes.

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[1] Cf. Vol. XII., Part I.
[2] HIST. REC./H/1650/10, pp. 171–172.
[3] 74/America/9.
[4] M.C. 1013.

It was also used in a lesser degree by the leather trade and for laboratory and sundry other uses. Under ordinary conditions more than three-quarters of the supply was imported by numerous merchants and distributed through a very large number of wholesale and retail dealers. So far as possible, the policy pursued was to distribute directly to consumers of considerable quantities in order to establish touch with their requirements and to avoid reduplication of licences and inflation of prices; but merchants who broke bulk and sold in small quantities, or those who had facilities for breaking down and repacking high-strength acid were used as distributors to numerous consumers of very small quantities, such as ink and roller varnish makers. Importation was practically stayed by an embargo placed by the United States Government upon the export of acetic acid in May, 1918. Private stocks of standard acid in the country had then already been exhausted and Government requirements had been reduced by changes in the poison-gas programme. Efforts were accordingly made to induce the trade to use the Government synthetic acid, the price for which was fixed at a relatively low figure to this end. The single British firm making pure acid was supplied with acetate of lime to the full capacity of its plant and was also aided by priority for machinery and repairs.

The earlier stages of control succeeded in providing certain essential Government supplies and in facilitating the organisation of the American raw material supply for dope manufacture. After export had been prohibited from the United States, the Ministry ceased to have any strong interest in regulating acetic acid consumption; but the order was maintained until December, 1918, mainly, to ensure the fair distribution of standard qualities, supplies of which were still far less than the trade demand.

An important product of the Weizmann process for acetone manufacture was butyl alcohol, these materials being manufactured in the proportion of one to two. Before the war, the use of butyl alcohol was restricted. As a consequence of the successful establishment of the process in Toronto, measures were taken during 1917 for converting the resultant butyl alcohol into methyl-ethyl-ketone; and the use of the latter as a solvent in cordite manufacture was successfully developed at the cordite factory of the Canadian Explosives Company, Ltd. Continuous working of the plant for converting butyl alcohol to methyl-ethyl-ketone was, however, delayed chiefly by mechanical troubles with the catalysers, so that the total output of pure methyl-ethyl-ketone down to November, 1918, was limited to 2,850 gallons.[1] Investigations made with a view to disposing of the large quantities of butyl alcohol, which would have been produced by the distilleries converted to acetone manufacture, showed that the only use of this material known was for the manufacture of butyl acetate as a substitute for amyl acetate, which is derived from fusel oil. An agent acquainted with the fusel oil markets was appointed to negotiate the sale of butyl alcohol produced

[1] HIST. REC./H/1530/17.

by the Weizmann process, until operations at the converted distilleries were discontinued in April, 1917. About 75 per cent. of the total quantity of butyl alcohol sold, went towards the manufacture of butyl acetate. The remaining 25 per cent. was used in making solidified fuel for " Camp " stores.

(*f*) Development of British Wood-Distillation Factories.

In October, 1917, proposals were made to extend the British plant for wood-distillation in order to make use of waste wood produced in the felling operations which were being organised by the Timber Supply Department of the Board of Trade, and to provide against the threatened shortage of acetic acid. The erection of new factories for wood-distillation was put in hand at Mid Lavant, in Sussex, at Ludlow, in Shropshire, and at Carmarthen. Construction of the first two of these factories was well advanced at the close of hostilities. They were therefore completed, but not put into operation. The Carmarthen factory never passed beyond the preliminary stages of construction.

These new factories were directly controlled by the Propellants Branch, together with the plants at Coleford, Bideford and Dundee, and the Longparish factory which was taken over from Messrs. Kynoch early in 1917. Acetate of lime was regarded as their main product, and charcoal, etc., as by-products. In the largest factory and at certain of the others, close regulation of the practice along scientific lines enabled the whole cost of operation to be more than covered by the value of the by-products alone. In May, 1917, responsibility for the sale of the by-products was transferred from the superintendents to headquarters. Direct touch was established with consumers. Practically the whole output of the factories was devoted to war purposes, and profiteering, for which the by-products had offered a useful field to merchants, was successfully eliminated.[1]

(*g*) American Supplies, 1917–18.

The arrangements made for British purchases of acetone in America for the year 1916 had succeeded in eliminating competition between the State and the trade ; but British negotiations for acetone and acetate of lime for 1917 were greatly prejudiced by independent inquiries on the part of the French and Italian Governments for comparatively small quantities. Hence, in May, 1917, the British Government became responsible for purchasing for Great Britain, France and Italy, all the acetone and acetate of lime then available, the final allocation being made by the Inter-Allied Bureau. During the following autumn, a similar arrangement was made in respect of the acetone, acetate of lime, and acetic acid requirements for 1918, and the supplies for Portugal were purchased in the same manner. Each Government undertook to pay for its respective allocations out of its own dollar credits.

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[1] Hist. Rec./H/1530/9.

As a result of continued pressure exercised through the British War Mission, the United States Government, acting through the United States Signal Corps,[1] established absolute control over the American wood-distillation industries as from December, 1917. Prices were fixed. Distribution was effected by means of the Signal Corps. Ultimate financial responsibility was to be shared in proportion to the domestic and military requirements of the United States and British Governments. The United States and British Governments each assumed one-half of the financial risks involved in giving financial aid towards increasing output. Great Britain undertook responsibility for the requirements of France, Italy and Portugal, with whom she made her own financial arrangements, whereby each Government paid to the British account in dollars in America for consignments of solvents or acetate of lime before delivery was made out of the pool. The three Allies were also requested to bear their *pro rata* share of any loss which might fall on the British Government in respect of balance of capital unamortized at the close of the war. This method of purchase was successfully continued until November, 1918.

Two distilleries were purchased in the United States and converted into acetone plant similar to that already in operation at Toronto. The one, bought from the Commercial Distilling Company, was transferred to the Commercial Solvents Corporation, the stockholders being the Director and Deputy-Director of Purchases in America. The other, intended chiefly to produce acetone for the American aviation programme, was purchased from the Majestic Distilling Company. It was to be jointly built and operated by the Governments of the United States and Great Britain. Each Government made equal advances to cover the cost of construction and equipment. The British Government received a pledge for 125 shares as security for a demand note for $1,100,000 (April, 1918); the United States Government, 120 shares for a similar note. The company agreed to deliver the products made at cost price without profit to each Government. The Majestic plant only started operations in November, 1918.

II. Alcohol for Munitions.

(*a*) Growth of the Demand for Alcohol as a Solvent.

Until the autumn of 1915, the use of alcohol for war purposes was practically restricted to the consumption of considerable quantities of methylated spirit in the manufacture of munitions, particularly for shell varnish, and for other purposes by various branches of the Admiralty and the War Office. About November, 1915, the industrial and methylating trades began to experience considerable difficulty in obtaining supplies of spirit from the distilleries, owing chiefly to the operation of the Immature Spirits (Restriction) Act, 1915. This

[1] For the work of the Corps, see Hist. Rec./H/1530/19.

Act provided that spirit for home consumption should be warehoused for at least three years, and in order to ensure a stock of potable spirit large quantities were being bonded, with the result that the quantity immediately available for industrial purposes was reduced.

In the meantime, decision had been taken so far as was possible to replace cordite M.D., made from acetone as a solvent, by cordite R.D.B., for which the solvent used was ether-alcohol. An enormous demand for alcohol for munitions was thus created as the trade factories gradually changed over to cordite R.D.B. during the winter of 1915-16, and as the great Government cordite factory at Gretna came into operation during the summer of 1916. It was calculated in September, 1915, that the supplies of home-produced spirits would be sufficient to meet these demands.

The position in regard to methylated spirit was remedied upon an appeal made by the Propellants Branch of the Ministry of Munitions to the patent-still distillers, many of whom had not before made alcohol for industrial purposes. The price to be paid for alcohol for Government use was negotiated with the patent-still trade, in reviewing whose prices consideration was given to the greater cost of manufacture from grain than from molasses, the decrease in the output available for the more profitable potable trade and the increases in the distilleries' revenue from the sale of by-products. Taking these considerations into account, the price for alcohol agreed in January to March, 1916, was 1s. 10d. per proof gallon as compared with 1s. 2d. per gallon, less 1d. rebate, the pre-war price for industrial spirit derived from molasses. This price was raised from time to time and was eventually agreed at 4s. per gallon from 15 July, 1918. It was always considerably lower than the charge made by the distillers to methylators or users of " duty free " spirit. The price to be paid by Government Departments for methylated spirit was agreed in June, 1916, with the Methylators' Association, whose standard prices were binding on individual methylators. The Association credited the Department with a rebate of 2d. per gallon each month. Upon receipt of a certificate from the Association, distillers credited direct to the Department concerned the difference between the price for spirit charged to methylators producing for trade purposes and that ruling for alcohol for the Government.

(*b*) Control of the Industry under Defence of the Realm Regulation 30D.

The patent still distillers, 27 in number, produced alcohol from grain or molasses, and in the early months of 1916 they met with some difficulty in importing sufficient materials by reason of the shortage of tonnage. Moreover, the demand for freight to carry materials for producing alcohol, which would not be potable for three years, was outweighed by more immediate and essential calls upon the limited tonnage available. Further, the scheme for producing acetone from grain by the Weizmann process necessitated the diversion of material and plant for this purpose. Accordingly, on 10 May, 1916,

an Order in Council was issued as Defence of the Realm Regulation 30D, prohibiting the use of grain, rice, sugar or molasses or other materials for the production of whiskey or alcoholic spirits except under a permit from the Minister of Munitions.[1] The prohibition became operative on 28 May following and brought the malt or pot-still distilleries in Scotland and Ireland under the virtual control of the Ministry, as well as the patent-still distilleries which alone produced alcohol of sufficient strength for the manufacture of propulsive explosives.

The pot-still distilleries were allowed to continue work in order to use up the grain already malted, and were subsequently licensed to make up to 70 per cent. of their normal output. The six patent-still distilleries which were converted to acetone production were not producing yeast in the manufacture of alcohol. The remaining 21 patent-still distilleries were all allowed to continue full output in order to balance the reduced production of strong alcohol for industrial and war purposes, and to maintain the supply of yeast. Sixteen of these produced alcohol and yeast from grain. The five other patents stills used molasses as a raw material.

The use of plain spirit for war purposes, which began in the winter of 1915-16, increased rapidly. During the year 1916, the amount so consumed was about 7,750,000 proof gallons. Towards the end of the year, the requirements of alcohol for making propulsive explosives began to increase, while the position was rendered more serious by difficulties experienced in recovering solvent. An advisory committee, appointed by the Minister of Munitions, and including representatives of the Board of Customs and Excise, the Board of Trade, and the Board of Agriculture, considered the method to be employed in increasing home production or imports. They concluded that the patent-still distillers would be able to increase their output to meet the augmented requirements provided the raw material was available.

(c) Grave Effects of the Shipping Position, 1917.

In the meantime, the shipping position was becoming more serious. Distillers decided voluntarily that from the beginning of 1917, no more spirit should be bonded for whiskey. As no stocks of gin existed, about 40 per cent. of their normal quantity of spirit was to be delivered to rectifiers for gin manufacture. In April, 1917, however, the Government came to the conclusion that the use of grain in making spirit for any potable purpose could not be defended, and the issue of new spirit for gin was stopped.

A system of returns showing the output and despatches from the distilleries was begun early in this year, and returns of receipts and issues of spirit were also requested from rectifiers and compounders in order to check the quantities consumed in gin manufacture and by other trades. These returns supplemented those already received as to the spirit delivered to methylators. Early in May, 1917, the supply of new spirit for any purpose except the manufacture of medical

[1] Appendix XVI.

preparations was stopped, and the spirit hitherto used in producing toilet preparations, essences and perfumery, thus became available for war purposes. In co-operation with the Methylated Spirit Makers' Association, the sale of mineralised methylated spirit for burning was practically stopped, and deliveries of industrial methylated spirit for making toilet preparations was restricted so far as was possible.

Attempts were made to import alcohol in place of its more bulky raw materials and certain quantities were brought from Durban; but the allocation of tonnage for bringing supplies from other colonies such as British Guiana and the West Indies, was refused, on the ground that foodstuffs would thereby be displaced.

At the beginning of May, 1917, the production of alcohol fell below requirements, since the non-yeast grain distilleries had been first set aside for acetone manufacture and afterwards closed, since the yeast distilleries were restricted to those mashes from which yeast was taken, and since the output of the molasses distilleries was reduced by the shortage of raw material. Public opinion against the use of grain in making spirit for industrial purposes had for some time been expressed in the form of questions in the House of Commons, and the consumption of bonded alcohol for this purpose had been urged. On the other hand, there was no apparent alternative to the continued operation of the yeast distilleries in order to produce yeast for bread. An inter-departmental committee, which was appointed in April, 1917, to consider this question, reported on 7 May, 1917, that the difficulties attached to reducing the quantity of yeast used in bread-making and the risks of producing unsuitable bread appeared to nullify the advantages which might be gained by reducing the quantities of grain used by distillers. Steps had already been taken to reduce the importation of foreign yeast, since it was known that continental distillers were sending their yeast to England, while the alcohol produced simultaneously was probably finding its way to Germany. The use of substitute leavens involved extra supervision and extra skill in the making of bread.

The Advisory Committee did not recommend that bonded potable spirit should be withdrawn for industrial use in view of the serious political consequences which were anticipated from such an action, particularly in Ireland. The quantity of bonded 1916 and 1917 spirit was estimated at 30,000,000 proof gallons, and would have more than sufficed for the whole consumption of plain spirit for war purposes in 1917, during which year the actual quantity used was about 25,500,000 proof gallons. On the other hand, this spirit had a very high market value. The stocks were held by merchants and blenders to whom large advances had been made by bankers on this security. Any panic in the trade which might have followed upon the commandeering of the bonded spirit would probably have resulted in a financial crisis involving £100,000,000. Moreover, permanent damage was anticipated to the home and export trade, whose reputation rested upon the proper blending of patent and pot-still whiskey.[1]

[1] HIST. REC./R/1510/1/12.

The Advisory Committee considered as alternative methods of meeting the deficiency of alcohol for war purposes, the importation of spirit from the colonies, and increased production from molasses. They recommended the latter course, advising that the tank steamers engaged upon importing molasses should be kept in constant service, and that their number should be augmented.[1] No decision had been taken in June, 1917; but it was found early in July, that a certain amount of "free" space was available for shipping alcohol from Demerara and the West Indies, and arrangements were made to accept any such shipments which could be effected.

During the later months of 1917, the position was improved by a reduction in the demand for cordite, and by increased efficiency in the recovery of the solvent. Supplies of grain to the yeast distilleries were maintained by the Royal Commission on Wheat Supplies. The imports of molasses were sufficient to keep the molasses distilleries working fairly well until certain of the tank vessels used for carrying molasses were diverted to the conveyance of oil-fuel for the navy in March, 1918, when, owing to further reductions in the gun ammunition programme, the demand for alcohol again decreased.

(*d*) Accumulation of Stocks for Toxic Gas Manufacture, 1918.

While, as a result of the reduction in the gun ammunition programme, the output of alcohol in the spring of 1918 exceeded the immediate demand for war purposes, a requirement for spirit for toxic gas manufacture increased gradually until in the autumn of that year, an ultimate demand for 1,000 tons weekly was anticipated. Arrangements were accordingly made to store the spirit produced in excess of current requirements for war purposes and the essential industries. The warehoused spirit was charged at the price ruling for supplies to the Government. The distillers lent casks without charge and stored the spirit in their bonded warehouses at the usual rates. The Ministry assumed the risk of losses from fire, or as the result of enemy action.

(*e*) Position at the Close of the War.

This arrangement was renewed for a period of three months on 31 October, 1918. Shortly afterwards, distillers experienced great difficulty in finding casks to store the alcohol, and after the Armistice they desired to be allowed to dispose of the surplus spirit for potable purposes, alleging that blenders had an ample stock of casks. At this time, the yeast distillers alone were allowed to produce only to the bare limit necessitated by the yeast requirements of the country. It was anticipated that pot-still distillers would agitate to begin working, if the bonded patent-still spirit were released for potable purposes; and that, apart from the question of supplies of grain for their use, the whole question of future policy as to distilling would thus be raised. In view of the shortage of casks, however, the Minister

[1] Hist. Rec./R/1510/1/13.

agreed on 30 December, 1918, to cease taking supplies of the surplus spirit on condition that the distillers continued to maintain the output of yeast, to distribute the spirit *pro rata* to their customers on the basis of their 1915 scale, and at a price not exceeding 5s. per gall., and to give preference to the requirements of the methylators and commercial spirit users over the potable trade. Finally, on 17 January, 1919, Defence of the Realm Regulation 30D. was revoked, reliance being placed upon the " Malt Restriction Orders " and the " Maize, Barley and Oats Restriction Order," to enable the Food Controller to regulate undue consumption of grain for alcohol production.

The following table gives the quantity of spirit in proof gallons used for war and industrial purposes from 1 August, 1914, to 31 March, 1919 :—

	Home Produced.		Spirit Imported for War Purposes.	Total.
	Plain Spirit for War Purposes.	Methylated Spirit for War and Industrial Purposes.		
1914 (Aug.–Dec.)	—	3,652,222	—	3,652,222
1915	—	8,888,267	—	8,888,267
1916	7,772,082	9,878,539	—	17,650,621
1917	25,658,613	8,549,390	1,279,004	35,487,007
1918	15,252,417	6,810,097	1,909,760	23,972,274
1919 (Jan.–March)	—	1,177,433	393,500	1,570,933
Totals	48,683,112	38,955,948	3,582,264	91,221,324

The stock of Government spirit in distillery bonded warehouses at the close of hostilities was 5,182,000 proof gallons. The total stocks of spirit belonging to the Ministry early in 1919 amounted to 10,042,043 proof gallons.

III. Glycerine, Oils and Fats.[1]

Before the war, glycerine was a comparatively unimportant by-product in the manufacture of soap, one hundredweight being produced in making a ton of soap. The development of an enormous demand for nitro-glycerine, for cordite production, gave to glycerine an increasing importance until the urgency of the cordite requirement was outweighed by the need for oleaginous materials for margarine manufacture during the last year of the war.

(*a*) The Requisitioning of Supplies, 1915.

The exportation of glycerine was prohibited by Order in Council on 5 August, 1914, under the " Exportation of Arms Act, 1900 " ; but no great shortage of the material was anticipated until July, 1915,

[1] Based upon Hist. Rec./H/1530/6, Chaps. V. and VI. ; Hist. Rec./H/1500/5/6 ; 1530/13,14 ; Hist. Rec./R/1510/11, 12.

when investigations were made by the Board of Trade as to the stocks and deliveries which would be available for the increased gun ammunition programme. In view of a prospective shortage then revealed, circular letters were issued by the Ministry of Munitions on 5 August, 1915,[1] requisitioning the whole of the country's output of crude and refined glycerine. It happened that a large stock (10,000 tons) existed in the hands of the soapmakers, who had been doing their utmost to establish entire control of this material, in view of long-standing disagreement with the explosives trade as to its price.[2]

The whole stock and output of glycerine from the soap and candle trades was acquired at standard rates which were fixed in September, 1915, after conference with the trades, at £59 10s. per ton for crude glycerine, and £87 per ton for dynamite glycerine. These prices were based upon a large transaction which had taken place in the previous July. They compared very favourably with those in free markets, such as Spain and America, where glycerine prices advanced very rapidly and fluctuated during the war between £300 and £185 per ton for dynamite quality. The British price fixed for dynamite glycerine (£87) was £2 above the normal rate, in order to encourage distillation.

Producers were called upon to make monthly returns of their glycerine output to the Board of Trade, as certain soapmakers took exception to supplying these figures to a temporary Department. They stated to the Ministry of Munitions the stocks available for immediate delivery and the estimated surplus available for the following six months. No deliveries without licence were permitted to the trade for any purpose, the chief industrial uses of glycerine being for medicinal purposes, the manufacture of certain foodstuffs such as fruit-preserving and brewing, printing, the finishing, dressing, or waterproofing of cloth, silk, and leather, and the manufacture of paint and colours.

(*b*) REDUCTION IN THE USE OF GLYCERINE FOR INDUSTRIAL PURPOSES.

The monthly licences issued to producers to deliver glycerine for industrial purposes were strictly limited. Supplies for certain uses, such as the baking, confectionery and perfumery trades, were entirely prohibited. In other cases, consumption was reduced gradually in order to allow time for substitutes to be found. Steps were taken to prevent waste in the glycerine-using industries of national importance. Consumption was reduced by these means from 400 to 40 tons per month. In January, 1917, this system of licences to producers to sell was replaced by a system of licences to pharmacists or consumers to buy, as a means of restricting industrial consumption still further. Industrial issues were thus limited to 10 tons monthly, a quantity which was supplemented by two or three tons of imported glycerine monthly. Experience showed that glycerine could be eliminated in medical and veterinary practice as well as in other important industries, but that it was essential for printing, for scientific and analytical purposes, in ships' telemeters

[1] 95/G/19; Appendix XVII. [2] HIST. REC./R/1515/1.

and for blasting explosives. The percentage of glycerine used in these explosives was, however, reduced by agreement with the trade, and their use was restricted to essential industries within the British Empire. In April, 1916, the exportation of soap containing more than 1 per cent. of glycerine was entirely prohibited and certain restrictions were placed upon exporting soap of lesser glycerine content.[1] To some extent, the savings thus effected were set off by new demands for glycerine for war purposes, *e.g.*, for the impregnation of anti-gas masks, for anti-freezing purposes in machine-gun jackets, for the recoil gear of guns and for certain of the Allies.

(*c*) STEPS TAKEN TO INCREASE SUPPLIES.

In January, 1916, the soapmakers agreed to do their best to bring their output of glycerine from the normal amount, estimated at 19,000 tons a year, up to about 22,000 tons. They recommended, as a measure of insurance, that fat-splitting plant should be erected for converting oils and fats into fatty acids and glycerine by the Twitchell process. Two firms erected plant for this purpose, and in one instance the Ministry bore a part of the cost.

Every available source of overseas supply was tapped for glycerine. In August, 1915, the Ministry took over certain contracts placed in France by a British firm and French glycerine was bought through agents until October, 1916, when the French Government undertook to release certain quantities, provided purchase was made through their agents. The quantities so purchased decreased later with difficulties of labour and transport and the shortage of imported oils. Other supplies were obtained from Switzerland, South America and Holland at prices considerably higher than those fixed for the British product, but low in comparison with the rates ruling in the United States.[2]

The British Government was enabled to obtain supplies of glycerine from neutral markets at these comparatively low rates, owing to its control over important sources of oil supply in West Africa and India. This favourable position enabled the Ministry of Munitions in conjunction with the War Trade Department, the Colonial, and India, Offices, and the Board of Trade, to impose certain " glycerine conditions " in 1916. Under these, licences for the export of oils from British Colonies and Protectorates were dependent upon an undertaking to supply to the Ministry, at the standard British prices, an amount of glycerine equivalent to that which could be extracted from the consignment.

In March, 1917, the requirements of glycerine for war purposes began to exceed deliveries. Substantial stocks, which had been built up by this date, were then gradually reduced, reliance being placed upon the stand-by fat-splitting capacity as a means of meeting any future emergency. Towards the end of the year, however, a new and very serious difficulty arose from reductions in the amounts of oils and fats available for soap manufacture, in view of the growing demand for margarine production.

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[1] *London Gazette*, 14 April, 1916. [2] HIST. REC./H/1500/5/6.

(*d*) THE SUPPLY OF OILS AND FATS.

In restricting the export of oleaginous substances from British Colonies and Dependencies, it had been ruled broadly that oilseeds might be freely exported to Allied countries, but that oils should not be sent to non-British destinations.

Whale oil was, in 1916, by far the cheapest source of glycerine supply. Almost all the whale-oil in the world was obtained from British territorial waters in the Antarctic, although whaling was mainly carried on by Norwegians. The whole supply was secured by appending to the licences issued for whaling in British waters a condition that the oil should be brought to a port of call in the United Kingdom, and, subsequently, that it should be sold in this country. In March, 1916, under Defence of the Realm Regulation 30A, the Ministry prohibited all dealings in whale-oil without licence, but sperm oil was excluded from the application of this Order in the following June. Arrangements had already been made in February, 1916, to take over the business of certain leading whale-oil merchants, who thenceforward acted as agents for the Ministry in respect to an undertaking from three of the leading soapmakers to render the whale-oil, so provided, suitable for soapmaking.

By these and other means a good stock of raw material was accumulated in the country during 1916. The interests concerned in oils, fats and oil seeds were various and difficult to distinguish, the trades concerned being soap and candle makers, oil splitters, seed crushers and oil extractors. In February, 1917, a separate branch of the Explosives Supply Department was formed to deal with the supply of oils and fats and the disposal of fatty acids. Its functions were transferred to the Ministry of Food in June, 1917.[1]

Towards the end of 1917 the Ministry of Food informed the Ministry of Munitions that the full quantities of oils and fats could not be allocated for soap manufacture during 1918. It was ultimately anticipated that the materials furnished in 1918 would only enable soapmakers to produce 14,000 tons of crude glycerine against their then current output of 24,000 tons, which itself was 5,000 tons yearly below the maximum requirement. Although a considerable reduction in the gun ammunition programme substantially relieved this position in February, 1918, it became increasingly clear that all imports of oils and oil seeds would be needed for edible purposes, and the Ministry of Munitions was urged by the Ministry of Food to obtain supplies of glycerine from sources other than the soapmakers.

An appeal was made to the Colonial Governments. Australia controlled the material more closely, increasing her shipments to South Africa and so relieving home supplies. South Africa reduced the margin of her stock which it was proposed to pool. Canada effected economies in the domestic consumption of glycerine, and applied the oil exchange scheme to all oils imported for soap manufacture. Several of the colonies also took part in schemes for erecting fat-splitting plant in the centres of oil production, with a view to shipping

[1] 95/O/105.

the maximum quantity of glycerine to Great Britain with the minimum allocation of tonnage. Three schemes were chosen for development. The one involved the splitting of Australian and New Zealand tallow in existing plants in Australia to provide for the whole of the South African requirements, and thus save the shipment of glycerine thither. Its main disadvantage was the high cost of the raw material, tallow, which would have brought the price of glycerine up to £600 per ton ; but against this there was placed the saving of freight to South Africa and the lack of any expenditure upon erecting or operating the plant. The second project was for erecting plant near Calcutta for splitting oil from the native oil mills. A third scheme was for establishing a factory to split cocoanut oil in Ceylon. Similar plans for splitting oils elsewhere were rejected on various grounds, one of the most important being a proposal to establish oil-splitting works on the West Coast of Africa. These plans were abandoned in favour of purchases of glycerine from the United States of America, when in the summer of 1918 it became evident that reliable supplies could thus be obtained. In July, 1918, sufficient American glycerine was bought to cover immediate needs. The respective merits of making further purchases in the States or developing the projects for fat-splitting in British territory were still under discussion at the close of hostilities. In the meantime, efforts had been made to reduce the consumption of glycerine by the institution of a process efficiency scheme among the soapmakers.

(*e*) Intervention in the Soap Industry.

Certain steps had already been taken in the spring of 1916 to ensure a higher yield of glycerine from soap production. In February, 1916, a direction was issued to the soapmakers limiting the proportion of resin to be used in making soap for the home market. In the following March alternative methods of manufacture were permitted with a view to producing more glycerine. The leading glycerine and oil-producing firms were declared controlled establishments under the Munitions of War Act in that same month.

British soapmakers had been placed in a disadvantageous position by the fixing of prices for their glycerine output in the autumn of 1915. They were thus competing with American traders, who were benefiting by enormous advances in a free market where the demand for crude glycerine was practically unlimited.[1] It was, moreover, maintained throughout the war that they should recover any rise in the cost of materials on the price of soap and not of glycerine. In order to balance these disadvantages and the restrictions already placed upon their methods of production, importation of foreign soaps was prohibited by the Board of Trade at the instance of the Ministry in March, 1916. The activities of the Department in keeping the soap trade supplied with raw materials have been narrated above.

[1] Hist. Rec./R/1510/12.

During the year 1917, soapmakers endeavoured to increase their output of soap as a means of augmenting their glycerine production. As the value of soap increased, the makers learned to get more out of their plants than their capacity as previously estimated, but the yield of glycerine did not improve in proportion to the materials used. With the subsequent shortage of materials it became essential to ensure the highest possible efficiency in regard to glycerine production. A subsection of the Propellants Branch of the Ministry was established for this purpose in March, 1918. Process returns were required from soapmakers and fat-splitters. Inspectors visited the soap factories and those engaged upon similar operations, such as oil refining, tallow melting, and the manufacture of lubricants and tallow dips.

Arrangements were made by the Ministry of Food to allocate suitable materials to the firms who lacked facilities for recovering glycerine ; but many cases of hardship occurred among these manufacturers, who received insufficient fatty acids. The allocation of neutral material was made to depend upon the efficiency of the soapmaker to a certain extent. In one or two instances allocations were temporarily withdrawn. In a few cases the Process Efficiency Section took over the management of uneconomical factories. These general efforts to improve glycerine efficiency raised the average yield from about 74 per cent. in 1917 to over 82 per cent. in the five months June to October, 1918.[1]

With the close of hostilities the control of glycerine consumption was relaxed. In November, 1918, a return was made to the original method of granting block licences to British glycerine producers. In the following December the control of glycerine instituted in September, 1915, was entirely suspended.

The aggregate supply of glycerine from the requisitioning of supplies in the summer of 1915 until the suspension of control in December, 1918, is shown in the following table :—

AGGREGATE DELIVERIES OF GLYCERINE, 1915–18.

Source of Supply.	*Crude.*	*Saponification.*	*Dynamite.*
Requisition	35,481	4,700	27,244
Oil exchanges	1,023	274	336
France	4,960	nil	nil
Holland	nil	nil	4,038
Other sources	633	253	3,307
Totals	42,097	5,227	34,925

[1] HIST. REC./H/1530/13.

The distribution of the various qualities of the material can be seen most clearly by the following table :—

AGGREGATE ISSUES OF GLYCERINE, 1915–18.

Destination.	*Crude.*	*Saponification.*	*Dynamite.*
Government Explosives Factories ..	14,371	4,562	10,047
Trade ,, ,, ..	18,164	414	8,537
South Africa	8,650	251	9,085
India	nil	nil	617
Allies	nil	nil	1,317
Special Government Requirements	2,056*	—	—
Medicinal uses	1,537*	—	—
Other industries	1,354*	—	—
Totals	46,132	5,227	29,603

* The quality of these supplies is not differentiated.

IV. Cotton Waste.[1]

Until the close of 1916, the Ministry of Munitions was only directly interested in the supplies of cotton waste needed for national factories for propulsive explosives. In negotiating cordite contracts to cover the year 1917, the Department undertook to provide the manufacturers with all raw materials including cotton waste.

Supplies of cotton waste for the Royal Gunpowder Factory had been purchased upon several small contracts until the summer of 1915, when it became necessary to purchase far larger quantities for the projected State factories, and to guard against any prospective failure of the explosive trade to obtain adequate supplies. The total production of the country did not then exceed 110 tons weekly, and the trade was confined to a few small dealers and a combine of larger dealers, the British and Foreign Supply Association, Ltd., which controlled nine-tenths of the market. The situation was rendered more difficult by recent advances in the price of raw cotton from 4½d. to 1/- per lb.

It was ultimately decided to place an assisted contract with the Association, rather than to control the market through the Defence of the Realm Regulations, and the dealers offered to place the whole of their resources at the disposal of the Government and, if necessary, to assist the Department in placing advantageous contracts elsewhere. It was agreed in September, 1915, that the Association should place its mills for treating cotton waste at the disposal of the Ministry and should act as the Department's technical advisers and as agents in purchasing overseas supplies of raw material to make up the enormous deficiency anticipated. Additional mills were acquired and machinery laid down by the Association, the Ministry bearing the

[1] Based on HIST. REC./H/1500/5/4 ; HIST. REC./H/1530/6, Chap. VII.

capital outlay. Manufacturing and administrative expenses were charged to the Department at actual cost, and the Association received £4 per ton on their deliveries for the six months ending 30 September, 1915, and thenceforward £2 per ton (about 3 per cent.).

These arrangements were made with a view to an ultimate output of 800 tons weekly of bleached cotton waste, of which about 300 tons were to be bought by the Department for the national factories, and the remainder to be available for the trade. The pre-war capacity for producing bleached cotton waste was about 70 tons weekly.

In the autumn of 1916, projects were made for establishing new mills to provide bleached cotton waste for the nitrocellulose powder factories, the erection of which was then contemplated. It was ultimately decided upon expert advice to install the new mills as a part of the explosive factories. In the meantime, the British and Foreign Supply Association had submitted a scheme for managing both the old and the new mills for a fixed fee, the Ministry to purchase its assets at book value in exchange for the cancellation of the previous agreement to operate the mills on a cost plus percentage basis. The scheme was applied to the existing mills, and the Ministry purchased the shares of the Association. The mills, so acquired on 3 August, 1917, were managed by the directors of the Association to whose number were added certain Ministry officials. This arrangement was modified in March, 1918, when the directors resigned, and the mills were placed under the direct control of headquarters with a view to a closer technical regulation of their operations.

When the additional mills were under consideration in connection with the nitrocellulose powder scheme, it became apparent that the available supplies of linters, the raw material used for this purpose, would be insufficient for the Allied requirements, and the decision was taken to replace linters by Indian cotton in British factories. Prices for cotton waste were also becoming inflated by reason of competition between the British and French Governments. In June, 1917, it was accordingly agreed between the two Governments, that French overseas purchases of unbleached waste should be restricted to France, the United States (linters), and Egypt; whilst British purchases should be made in the home market in India, China, Japan and the United States (oily waste only). Deficiencies were to be made up with raw cotton, and surpluses to be available to either country. As a result of this arrangement, unbleached waste was obtained at greatly reduced prices, and the Ministry of Munitions, acting through the British and Foreign Association, practically monopolised the home market.

APPENDICES.

APPENDIX I.

(CHAPTER II, p. 13.)

Notification of the Requisitioning of Toluol Stocks.

27 *November,* 1914.

Gentlemen,

I am directed by the Secretary of State for War to state that he is of the opinion that it is necessary, in the present circumstances, that he should take possession of all the supplies of toluol available in the United Kingdom. A representative of the Department will therefore call upon you at an early date with the necessary requisitioning order. Pending his visit, I shall be glad if you will obtain the written authority of this Department before making further deliveries.

I am, etc.,
U. F. WINTOUR,
Director of Army Contracts.

APPENDIX II.

(CHAPTER II, p. 14.)

Covering Letter to all Coal-Tar Producers or Distillers, 3 December, 1914.

War Office,
London, S.W.

The Army Council hereby notify to you that they require you to place at their disposal, for the period of the present war, the whole output of your undertaking in toluol or substances containing toluol (such as commercial benzol, light oils or solvent naphtha), so far as the same are not covered by existing contracts.

As the Council are desirous of interfering as little as possible with existing contracts for the sale and distribution of these products, they will endeavour to leave in your hands such portion of your output as is covered by those contracts, so as to enable you to perform all such contracts as you have already entered into with regard to any portion of such output.

The possibility of so doing must, however, depend on whether it is consistent with the requirements of National Defence. Should you therefore have entered into any such contracts prior to this date, you are requested to give notice of same with full particulars of each contract to the Secretary of the Committee on the Supply of High Explosives, Storey's Gate, S.W., to whom all further correspondence on this subject should be addressed. The particulars asked for should reach the Secretary of the Committee not later than 5 December, and they will at once be considered, and the decision with regard to the portion of your output which they cover will be duly communicated to you.

R. H. BRADE.

APPENDIX III.

(CHAPTER II, p. 14.)

First Circular to Gas and Coke-Oven Undertakings not treating their own Tar.

War Office,

London, S.W.

3rd December, 1914.

Gentlemen,

I am commanded by the Army Council to draw your attention to the accompanying notice, that they have thought it advisable to take the whole output of your undertaking in toluol and carbolic acid or substances containing the same during the whole period of the war, so far as the same is not covered by existing contracts.

The Army Council are informed, however, that it is the practice of your Company to sell your tar, and not yourselves to treat it. In this case, they trust that it will be possible to continue the present arrangements during the period of the war, but for that purpose it is necessary that they should receive promptly particulars of the existing contracts as mentioned in the accompanying notice, as otherwise there may be inconvenience and delay.

I am, etc.,

R. H. BRADE.

APPENDIX IV.

(CHAPTER II, p. 14.)

Circular to Coke-Oven Undertakings distilling their own Tar.

War Office,

London, S.W.

3rd December, 1914.

Gentlemen,

I am commanded by the Army Council to draw your attention to the accompanying notice that the Government have thought it advisable to take the whole output of your undertaking in toluol or substances containing the same during the whole period of the war, so far as the same is not covered by existing contracts.

The Army Council would be greatly obliged if you would inform them whether you are distilling your own tar, and if so how far you carry the distillation, *i.e.*, whether you manufacture pure benzol and pure toluol, or only commercial benzol and commercial toluol, and also what are approximately the quantities of the above which your distilling plant is capable of treating, and whether it is fully occupied; and—in case it is not fully occupied—what further quantities it would be able to treat.

If you are not carrying the separation so far as is mentioned above, and only manufacture, but do not further treat your crude benzol and light oils, will you kindly give approximately the amount of these substances which you obtain and to what extent your distilling plant would enable you to deal with larger quantities ?

Does your plant include apparatus for recovering benzol, etc., from the gas, and, if not, could such plant be installed on your premises ?

I am, etc.,

R. H. BRADE.

APPENDIX V.

(CHAPTER II, p. 15.)

Circular to Tar Distillers and Gas Undertakings distilling their own Tar.

War Office,

London, S.W.

3rd December, 1914.

Gentlemen,

I am commanded by the Army Council to draw your attention to the accompanying notice that the Government have thought it advisable to take the whole output of your undertaking in toluol or substances containing the same during the whole period of the war, so far as the same is not covered by existing contracts.

They would be greatly obliged if you would inform them how far you carry the separation of the tar products, *i.e.*, whether you manufacture pure benzol and pure toluol, and also what are approximately the quantities of the above which your distilling plant is capable of treating, and whether it is fully occupied, and, in case it is not fully occupied, what further quantities it would be able to treat.

If you are not carrying the separation so far as is mentioned above, and only manufacture, but do not further treat, your crude naphtha and light oils, will you kindly give approximately the amount of these substances which you obtain and to what extent your distilling plant would enable you to deal with larger quantities ?

I am, etc.,

R. H. BRADE.

APPENDIX VI.

(CHAPTER II, p. 15.)

Second Circular to Gas and Coke-Oven Undertakings not treating their own Tar.

Committee on the Supply of High Explosives,
Storey's Gate, S.W.
15*th December*, 1914.

Sir,

With reference to your reply to my Committee's circular, I am directed to inform you that my Committee authorise you to continue deliveries of your crude tar to Tar Distillers.

If you are proposing to renew your contracts or negotiate new contracts with Tar Distillers, my Committee likewise have no objection to such action.

With regard to small sales to other parties, they have no objection to deliveries being continued until further notice provided that such sales do not in the aggregate constitute a substantial portion of your total output.

I am, etc.,
R. R. ENFIELD,
Secretary.

APPENDIX VII.

(CHAPTER II, p. 15.)

Notification of the Limitation of Control to Products containing more than 3 per cent. Toluol.

Committee on the Supply of High Explosives,
Storey's Gate, S.W.
17 *December*, 1914.

Sir,

Referring to the recent circular letter of the War Office, I am directed by the Committee to inform you that for the present they do not wish to interfere in any way with deliveries or sales of benzol, naphtha, etc., which contain less than 3 per cent. toluol.

The express authority, however, of this Committee, must be obtained for the export of toluol, benzol, naphtha, etc., and for all deliveries within the Realm which contain more than 3 per cent. toluol.

I am, etc.,
R. R. ENFIELD,
Secretary.

APPENDIX VIII.

(CHAPTER II, p. 22.)

Notice requiring Gas Undertakings to continue the Scrubbing of Gas, November, 1915.

Ministry of Munitions of War,
Director of Explosives Supplies,
Storey's Gate, Westminster, S.W.

Gentlemen,

1. I am directed by the Minister of Munitions to inform you that, in order to obtain an increased production of war material from your works, he finds it necessary to make certain requirements as to the methods of manufacture employed therein.

2. In exercise, therefore, of the powers conferred by Regulation 8A of the Defence of the Realm (Consolidation) Regulations (powers which may be exercised concurrently by the Minister of Munitions by virtue of the Ministry of Munitions Order, 1915), the Minister of Munitions hereby requires you, by scrubbing your make of gas with oil or tar in such manner as may from time to time be directed by the Minister to extract from such gas, such benzol, toluol, xylol, or other constituents as may be required by the Minister of Munitions, and to dispose of the whole of the materials thus extracted as directed from time to time by the Minister.

3. I am to add that you will find that compliance with the terms of this notice will relieve you of any forfeiture or other penal con sequences in case the necessity of complying with the requirements of the Minister of Munitions causes any failure on your part to keep your gas up to the illuminating or calorific standard imposed upon you by law.

I am, etc.,
MOULTON.

APPENDIX IX.

(CHAPTER II, p. 22.)

Explanatory Letter accompanying the Notice to Gas Undertakings.

Ministry of Munitions of War,
Director of Explosives Supplies,
Storey's Gate, Westminster, S.W.
November, 1915.

Sir,

I am directed to hand you herewith a letter signed by the Director General of Explosives Supply, requiring you to scrub your gas "in such manner as may from time to time be directed by the Minister."

You are already scrubbing your gas by the "C" process, and it is not suggested that any alterations should be made in the process at the present time, but this notice is given you, in order to protect you in the event of complaints being made that the quality of your gas has deteriorated.

I am, etc.,

F. L. HALFORD.

APPENDIX X.

(CHAPTER II, p. 22.)

Letter to Local Authorities relating to the Scrubbing of Gas.

Ministry of Munitions of War,
Director of Explosives Supplies,
Storey's Gate, Westminster, S.W.

November, 1915.

Sir,

I am directed to hand you herewith a copy of a notice which has been given to the Gas Company.

Owing to the demand for benzol and toluol for the manufacture of explosives, it has been found necessary to require gas undertakings throughout the Kingdom to extract these constituents from their gas, thereby in some cases affecting the illuminating values of the gas, and possibly also, in some very slight degree, its calorific power.

The increasing of the available supplies of benzol and toluol is a matter of national importance, and it is felt that every effort should be made to prevent gas undertakings from being penalised or interfered with in any way for meeting the national needs.

I am accordingly to suggest that you should do everything in your power to prevent attacks being made on the gas undertaking in question, owing to any possible deterioration in the quality of the gas supplied, and it is thought that this can best be done, either by ceasing to test the gas altogether, or at any rate by preventing the results of the tests being made public.

I am, etc.,

F. L. HALFORD.

APPENDIX XI.

(CHAPTER II, p. 23.)

Defence of the Realm Regulation 8G, Control of the Manufacture of Gas, 11 May, 1918.

8G. It shall be lawful for the Admiralty or Army Council or the Minister of Munitions to require the manufacture or production of gas in any gas-works to be carried out in accordance with any directions, regulations or restrictions given, made or imposed by the Admiralty, Army Council, or Minister of Munitions with the object of making such gas-works or the plant or labour therein as useful as possible for the production of any war material or any articles required for or in connection with the production thereof and in particular to require that all or any part of the toluol, benzol or other hydrocarbons contained in the gas produced or any other constituents of such gas shall be extracted therefrom, by scrubbing or otherwise, before the gas is supplied to the consumers in the district supplied by such gas-works.

The occupier and every officer and servant of the occupier of the gas-works and any persons affected by any such directions, regulations or restrictions and, where the occupier is a corporation or company, every officer of such corporation or company shall obey such directions, regulations or restrictions (notwithstanding the requirements of any statute or statutory order with regard to the illuminating or calorific power of the gas supplied from such gas-works) and if he fails to do so he shall be guilty of a summary offence against these regulations.

APPENDIX XII.

Schedule of Control Orders relating to Coal-Tar Products.[1]

(CHAPTER II.)

Title of Order.	Date.	Effects.	Reference in Text.
1. Coal-Tar or Coke-Oven By-Products.	31 Oct., 1916	Requires returns.	p. 31
2. Creosote and other Oils produced from the distillation of Coal-Tar.	13 July, 1917	Subjects to licence use of such oils for treating wood or road-making; subjects dealings to licence.	p. 29
3. Creosote and other Oils with a specific gravity of 1·000 or more.	13 July, 1917	Requires returns from consumers.	p. 29
4. Crude Benzol, Naphtha and Light Oils.	29 Aug., 1917	Subjects dealings to licence; requires returns.	p. 29
5. Coal-Tar	4 Sept., 1917	Subjects dealings in quantities above 10 gallons to licence, except purchases for distillation.	p. 29
6. Tar Oils	23 Oct., 1917	Takes possession of tar-oil fractions suitable for fuel; subjects to licence dealings in, and use of, any tar-oil; fixes maximum prices; requires returns.	p. 30
7. Tar (Coal and Water Gas) 1917.	31 Dec., 1917	Extends terms of Coal Tar Order, September, 1917, to water-gas tar; prohibits use of tar for certain purposes (*e.g.*, firing, steam raising, heating); subjects to licence use of tar for other purposes.	p. 30
8. Naphtha, 1917 ..	31 Dec., 1917	Subjects dealings to licence; requires returns.	p. 29
9. Tar Oils Control, 1918	1 Feb., 1918	Takes possession of all tar oils, except those controlled by Orders 4 and 8 above; subjects to licence dealings in, and use of, such oils; fixes prices; requires returns.	p. 30
10. Fertiliser Prices, 1918	30 April, 1918	Relates *inter alia* to sulphate of ammonia. *See* Appendix XV, No. 9.	p. 32
11. Ammonia Control, 1918.	17 May, 1918	Subjects manufacture of ammonia and ammoniacal products to licence and methods of manufacture to instructions; subjects sales to licence; requires returns.	p. 32

[1] The full text of these Orders appears in current issues of the *London Gazette* and in the various *Manuals of Emergency Legislation.*

APPENDIX XIII.

(CHAPTER III, p. 42.)

Circular fixing Maximum Prices for Sulphuric Acid.

Ministry of Munitions of War,
Department of Explosives Supplies,
Storey's Gate, Westminster, S.W.

11*th February*, 1916.

Gentlemen,

In accordance with the recommendation made by the Government Advisory Committee on Production and Distribution of Sulphuric Acid, and communicated to this Department on 6 January, 1916, the Minister of Munitions has decided that the following maximum prices should not be exceeded in the sale of acid for any purpose :—

	Degrees Twaddell.	*Maximum price per ton for acid delivered into railway trucks, cart or barge, at maker's works.* £ s. d.
Class A.—Arsenical Acid	140	3 0 0
Class B.—De-arsenicated Acid ..	144	3 15 0
Class C.—Arsenical Acid	168 (93%—95% H_2SO_4)	5 15 0
De-arsenicated Acid ..	168 (93%—95% H_2SO_4)	6 0 0

This Department has also adopted the following recommendations of the Advisory Committee with regard to incidental charges for all classes of acid :—

1. When the acid maker supplies the tank trucks he shall be entitled to make a further charge of not more than 5s. per ton for filling and hire of tank trucks.

2. When the acid maker supplies the acid in his own drums he shall be entitled to make a further charge of not more than 10s. per ton for filling and hire of drums.

3. When the acid is supplied in the acid maker's own carboys, he shall be entitled to make a further charge of £1 per ton for filling and hire of carboys. (When carboys are supplied by the purchaser, this Department recommends that a charge of 10s. per ton should be made by the acid maker, to cover the cost of filling.)

I am directed to inform you that the maximum prices will come into force on 14 February, 1916, and that they will apply to all sales of acid made after that date. You will be required to furnish particulars of your output of acid and of all sales of acid made by you. Forms for this purpose will be supplied to you in the course of a few days.

I am, etc.,

R. SOTHERN HOLLAND,

Deputy Director-General of Explosives Supplies.

APPENDIX XIV.

(CHAPTER III, p. 42.)

Circular revising Maximum Prices for Sulphuric Acid, 30 December, 1916.

Ministry of Munitions of War,
Explosives Department,
Storey's Gate, Westminster, S.W.
30 *December*, 1916.

Gentlemen,

MAXIMUM PRICES FOR SALES OF SULPHURIC ACID.

With reference to the Department's circular letters of 11 and 28 February, 1916, whereby maximum prices for the sale of sulphuric acid were fixed, the Minister of Munitions considers it necessary to cancel the figures given therein and to substitute the following, which refer to sales of sulphuric acid of all descriptions and for all purposes, unless expressly excepted :—

		Maximum price per ton for acid delivered into tank wagon, cart or barge at makers' works.	
		s.	d.
Class A.—Arsenical Acid ..	140° Tw. at 60° F.	70	0
Class B.—Non-arsenical or De-arsenicated ..	144° Tw. at 60° F.	85	0
Class C.—Arsenical	95% H_2SO_4	130	0
Class D.—Non-arsenical or De-arsenicated ..	95% H_2SO_4	140	0

ALLOWANCES FOR VARIATION IN STRENGTH.

With regard to sales of acid of strengths other than those given above, the Minister recommends that the following adjustments in price should be made :—

Classes A and B comprise acid containing 90 per cent. or less H_2SO_4.

In the case of acid in Class A, an adjustment of 5d. per degree Twaddell should be made in respect of each complete degree by which the specific gravity differs from 140 deg. Tw., at 60 deg. F.

In the case of acid in Class B, an adjustment of 6d. per degree Twaddell should be made in respect of each complete degree by which the specific gravity differs from 144 deg. Tw., at 60 deg. F.

Classes C and D.—All acid of over 90 per cent. H_2SO_4 is contained in these classes. Payment should be made on the basis of percentage of monohydrate in each consignment. The following scales for payment are recommended :—

	Arsenical.	*De-arsenicated or non-arsenical.*
	£ s. d.	£ s. d.
Over 90% and up to 91%	5 3 0 ..	5 13 0
,, 91 ,, 92	5 9 0 ..	5 19 0
,, 92 ,, 93	5 15 0 ..	6 5 0
,, 93 ,, 93½	6 1 0 ..	6 11 0
,, 93½ ,, 94	6 4 0 ..	6 14 0
,, 94 ,, 94½	6 7 0 ..	6 17 0
,, 94½ ,, 95	6 10 0 ..	7 0 0
,, 95 ,, 95½	6 15 0 ..	7 5 0
,, 95½ ,, 96	7 0 0 ..	7 10 0

,, 96, in both cases, an additional 1s. for each complete $\frac{1}{10}$ %.

Packages.

1. When the acid maker supplies the railway tank wagons, he shall be entitled to make a further charge of not more than 5s. per ton for filling and hire of such wagons.

2. When the acid maker supplies the acid in his own drums, he shall be entitled to make a further charge of not more than 10s. per ton for filling and hire of drums. When drums are supplied by the purchaser, a charge of 2s. per ton may be made to cover the cost of filling.

3. When the acid is supplied in the acid maker's own carboys, he shall be entitled to make a further charge of £1 per ton for filling and hire of carboys. When carboys are supplied by the purchaser, a charge of 5s. per ton may be made by the acid maker, to cover the cost of filling.

Notes.

1. The maximum prices apply to sales of sulphuric acid made by sulphuric acid makers and their agents, but not to sales by dealers and merchants who are themselves not makers of sulphuric acid.

2. Merchants and dealers will be required to furnish a monthly return of sales (of sulphuric acid), made by them, setting out the prices charged in each instance.

3. The maximum prices do not apply to exports of sulphuric acid under permit to persons, companies or firms abroad, nor do they apply to the sale of sulphuric acid imported from abroad.

4. The maximum prices do not apply to the sale of sulphuric acid made wholly from brimstone, or to sulphuric acid specially purified for laboratory purposes.

5. In cases where a maker of sulphuric acid has, in order to supply his customers, to purchase supplies of acid from a third party,

it will be permissible for him, in so far as this is a departure from his normal procedure, to charge to his customers any extra cost of carriage thereby incurred.

I am directed to inform you that the above maximum prices will come into force on 1 January, 1917.

I am, etc.,

K. W. PRICE,

Deputy Director-General of Explosives Supply.

APPENDIX XV.

(CHAPTER III.)

Schedule of Control Orders relating to Acids and Fertilisers.[1]

Title of Order.	Date.	Effect.	Reference in Text.
1. Sulphuric Acid ..	29 May, 1917	Subjects manufacture and dealings to licence; restricts use of strong sulphuric acid; fixes prices, except for export; requires returns.	p. 43
2. Superphosphates ..	20 Aug., 1917	Fixes prices, except for export; requires returns.	p. 48
3. Compound Fertilisers, 1917.	13 Oct., 1917	Fixes prices except for export; requires returns.	p. 49
4. Superphosphates ..	17 Nov., 1917	Extends provisions of the Order of 20 August, 1917, to sales for export.	p. 49
5. Nitrate of Soda ..	18 Oct., 1917	Applies D.R.R. 30A to nitrate of soda.	p. 57
6. Superphosphates (Amendment) 1918.	28 Mar., 1918	Revises maximum prices.	p. 49
7. Sulphuric Acid (Amendment of Prices) 1918.	10 May, 1918	Revises maximum prices.	p. 47
8. Ammonia Control, 1918	17 May, 1918	Relates to ammoniacal products including sulphate of ammonia; *see* Appendix XII, No. 11.	p. 32
9. Fertiliser Prices, 1918	30 April, 1918	Fixes prices of superphosphates, sulphate of ammonia and ground basic slag, equalising cost of distribution; subjects certain sales to licence; fixes minimum consignments.	p. 50
10. Compound Fertilisers, 1918.	4 June, 1918	Fixes prices on same basis as in Compound Fertiliser Order, 1917, widening definition of fertiliser.	p. 50
11. Sulphuric Acid (Amendment of Prices) No. 2, 1918.	8 Nov., 1918	Revises prices.	p. 47

[1] The full text of these orders appears in current issues of the *London Gazette* and in the *Manuals of Emergency Legislation*.

APPENDIX XVI.

(CHAPTER IV, p. 75.)

Defence of the Realm Regulation 30D, Restriction of the Use of Grain in the Manufacture of Spirits.

30D. After the twenty-eighth day of May, nineteen hundred and sixteen, no person shall without a permit issued under the authority of the Minister of Munitions, use or permit to be used any grain, either malted or unmalted, rice, sugar, or molasses, or any other material which may for the time being be specified in an order issued by the Minister of Munitions, in or for the manufacture or production of whiskey or any other alcoholic spirits, and if any person acts in contravention of this provision, or fails to comply with any condition subject to which a permit under this regulation has been granted, he shall be guilty of an offence against these regulations.

APPENDIX XVII.

(CHAPTER IV, p. 79.)

Circular requisitioning the Output of Glycerine.

Ministry of Munitions of War,
6, Whitehall Gardens,
London, S.W.
5 *August*, 1915.

Gentlemen,

I am directed by the Minister of Munitions to inform you that he considers it necessary to requisition the whole production of crude or refined glycerine throughout the United Kingdom.

In exercise, therefore, of the powers conferred upon him by the Defence of the Realm Consolidation Act, 1914, the Defence of the Realm (Amendment) No. 2 Act, 1915, the Defence of the Realm (Consolidation) Regulations, 1914, the Ministry of Munitions Act, 1915, and the Ministry of Munitions Order, 1915, he thereby requires you to place at his disposal the whole of your output of crude and refined glycerine.

I am further to require you to furnish forthwith to the Director-General of Explosives, Storey's Gate, Westminster, S.W., full particulars of your stock of crude and refined glycerine, and a list of all contracts which you have already made for the delivery of either.

The Minister will be prepared to consider any representation which you may address to him with a view to continuing to make deliveries on contracts concluded before the receipt of this letter.

I am, etc.,

H. LLEWELLYN SMITH.

APPENDIX XVIII.

(CHAPTER II, p. 20.)

Table showing the Recovery of Crude Benzol from By-product Coke Ovens, 1913–1917 :—[1]

Year.	*Tons.*
1913	75,682
1914	87,508
1915	100,594
1916	124,324
1917	134,493

[1] HIST. REC./H/1510/1.

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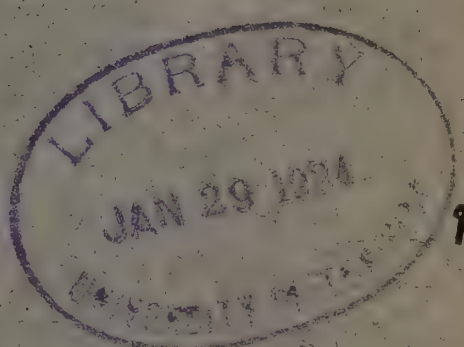
HISTORY OF THE MINISTRY OF MUNITIONS

VOLUME VII

THE CONTROL OF MATERIALS

PART V

TRANSPORT, STORAGE AND SALVAGE



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Volume VII

THE CONTROL OF MATERIALS

PART V

TRANSPORT, STORAGE AND SALVAGE

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CHAPTER I.

OVERSEAS TRANSPORT.

I. Geographical Survey of the Sources of Supply.

The outbreak of war deprived Great Britain of the supply of certain essential commodities from Central Europe, but, by arresting German overseas trade, it also threw open to her additional sources of supply. Colonial, allied and neutral resources were practically at her disposal in spite of difficulties arising out of the blockade, and, apart from the difficulties arising from an adverse exchange, the chief problem with which she was faced was the shortage of carrying capacity. Munition imports during the war averaged 11,832,000 tons yearly and were approximately equal to imports of food.[1]

It is impracticable to measure exactly the imports for munitions purposes during the war, partly because many materials served a double use, partly because record was only kept in this form at a comparatively late date. The table in the Appendix gives some idea of the minimum of imports, which went directly to munitions production, by showing the tonnage of the most important munitions or munition materials brought from overseas between 1915 and 1918 The aggregate of these was 46,000,000 tons, by far the largest item being nearly 26,000,000 tons of iron ore imported from Spain and Scandinavia. The difficulty experienced in obtaining shipments on so large a scale grew as the war progressed. The very expedients introduced for obviating the general shortage of shipping in 1917 and 1918, bore particularly heavily upon munitions imports. Arrangements for concentrating ships on shorter voyages diminished the tonnage available for bringing essential materials from distant ports, for example, lead and spelter from Australia and nitrates from Chile. The system of voyages in convoy aggravated the difficulties already experienced in expediting the discharge of vessels and regulating dock-side labour. The chapter which follows illustrates the methods used for overcoming these difficulties, whilst the introductory geographical survey shows how vast a problem was involved in bringing to this country the materials needed for munitions production.

(*a*) United States and Canada.[2]

Soon after the outbreak of hostilities, Great Britain turned to the United States of America and to Canada for immediate supplies of finished arms and equipment, and during the first year of the war

[1] In 1917, shipments of munitions and materials amounted to 15,000,000 tons and food imports to 14,000,000 tons out of a total of 37,000,000 tons. (Hist. Rec./R./2060/15).

[2] For a more detailed account of munition supply from the United States *see* Vol. II, Part III, and from Canada, *see* Vol. II, Part IV.

machinery and finished munitions were conveyed to these shores in ever increasing quantities. When British engineering resources were more completely organised during the summer of 1915, enormous shipments of raw materials from America were added to the imports of finished guns and ammunition. The chief of these materials were copper, lead—of both of which the United States was the prime world producer—iron ore, spelter, zinc ore, aluminium, acetone, petroleum, wolfram, carborundum, tungsten, rosin, hardwood timber, as well as spruce, turpentine, quicksilver, cotton and ferro-vanadium.

A similar condition of things obtained in the case of Canada. The greater part of the supplies from the dominion originally consisted of shells and finished munitions, but latterly of raw materials. Of these last, the chief were copper, aluminium, calcium carbide, chrome ore, ferro-silicon, and nickel. It was practically in Canada only that nickel was found in a concentrated form, and in 1916 the Canadian output formed 85 per cent. of the total production (49,000 tons). The Canadian shipbuilding yards also supplied Great Britain with shipping, and in spite of high freights, exports of timber for ships and aeroplanes steadily increased in volume.[1]

(*b*) Greenland, Iceland, Scandinavia and Russia.

This group of countries furnished the United Kingdom with numerous commodities vital to the manufacture of munitions. Raw cryolite for treating aluminium in Norway was obtained from Greenland. From Iceland came whale oil, from Norway iron ore, pyrites, spelter, ammonium nitrate, calcium nitrate, calcium carbide, nickel steel, ferro-silicon, ferro-chrome and aluminium, and from Sweden iron ore, bar iron, pig iron, steel scrap, perchlorate of ammonia, turbine discs, ball bearings and gauges. British dealings in Swedish iron ore were partly in the nature of "blockade purchases" intended to prevent it from reaching the enemy; but a certain quantity of Swedish iron was essential for the production of certain kinds of steel.[2]

In July, 1915, a British mission was sent to Sweden to purchase iron ore, and Messrs. C. J. Hambro were appointed Government Agents to make payments against documents.[3]

Bergen was the chief port for supplies from Norway and Sweden, and Norwegian shipping was almost exclusively employed in this trade. The sea route for Swedish exports was from Gothenburg to Hull, the Baltic ports being too dangerous; but when the submarine danger

---

[1] For a more detailed account of the American timber supplied for aircraft, *see* Vol. XII, Part I, pp. 123-125.

[2] Hist. Rec./R./1810/63; Hist. Rec./H./1810/2. For accounts of purchases of Scandinavian ores *see* Vol. VII, Part II, pp. 32–34, and of "blockade purchases" *see* Vol VII, Part I.

[3] In January, 1917, it was arranged that this firm should purchase kroner exchange by sterling funds received through the Ministry from the Treasury fund in Scandinavia, and not by special purchase in the market. For purchases from Sweden of perchlorate of ammonia prices were fixed in kroner or in sterling; for Swedish ore and iron in large quantities, payment was mostly in kroner or sterling equivalent at the current rate of exchange. Payment for Norwegian pyrites was made in sterling. (Hist. Rec./R./1810/64).

became serious in the spring of 1917, cargo ships and barges clearing for British ports coasted up to Bergen, whence they found frequent escort to our north-eastern ports. At a later stage materials, even from the south of Sweden, were railed to Bergen and shipped thence to England.

The essential imports from Russia were manganese peroxide, asbestos (indispensable to the electrical industry), flax, timber and platinum, imports of the latter, down to the time of the Russian Revolution, valuing about 3 million roubles per annum. The Black Sea ports being closed, the only available routes for Russian commodities were (a) from Murmansk and Archangel on the White Sea, and thence round the North Cape ; (b) by rail through Finland, Sweden and Norway to Bergen, and (c) *via* the Siberian railway to Vladivostock and thence by sea. Russian timber came mostly on requisitioned ships from Archangel ; whilst the Hudson Bay Company's ships loaded motors, aeroplanes, etc., at Brest for Archangel and returned with grain bought by France from the Russian Government.[1]

(*c*) HOLLAND.[2]

From the Netherlands were brought glycerine (a blockade purchase), dynamite, and brass caps for electric lamps. The importation of these articles from Holland, with large quantities of margarine, and the export of the raw materials for the latter laid a great strain upon British maritime resources and necessitated the employment of a convoy of about 11 ships weekly to and from Rotterdam. Payment was made in sterling at the fixed rate of 11·60 florins to the £.

(*d*) FRANCE, SPAIN, PORTUGAL AND SWITZERLAND.

From France our imports of war equipment and materials were mainly confined to bauxite, aluminium, aeroplanes and parts, fuses, glycerine, glass and walnut wood. Coal ships directed to Bay ports mostly returned with iron ore and pyrites from Spain, and picked up on the round voyage at Bordeaux, S. Nazaire and Brest the materials for shipment to British ports. Freights were high, in view of the heavy sea risks, the West end of the Channel from Brest to Penzance being particularly open to attack. The French Government provided credit for Great Britain in France against sterling credits provided for her here. The latter were the greater, and the balance took the form of a loan to France.

From Spain the principal imports were iron ore, copper and lead. Among all countries exporting hematite, Spain stands first, and in 1913 no less than 76 per cent. of the British imports of this ore came from that country, while the pyrites mines could supply the whole world's requirements of sulphuric acid. In spite of the fact that the Spanish route was more exposed to enemy attack than that of any other munition supply, the United Kingdom was enabled to import these vital commodities, largely owing to an agreement to ship a certain amount of coal to meet Spanish needs. Requisitioned ships were seldom employed, and free chartering was the rule, although freights ruled high, despite the services of a government broker.[3] Payment

[1] R.S.C./Gen./209. [2] C.R.V./H./079. HIST. REC./R./1011/2. [3] *See* below, p. 9.

in respect of purchases was made in sterling to the amount of £3,972,135 in 1917. From Portugal, which early entered the war as a belligerent, the only import of material value was wolfram.

From Switzerland large quantities of fuses and minor components for gun ammunition were obtained, payment being made in francs, at about 24·65 francs to the £1 sterling.[1]

(*e*) The Mediterranean and North Africa.

To this sphere belong not only the Spanish and French ports of the region, but also Algiers, Morocco, Tunis, Italy and Greece, from all of which supplies were drawn. From Algiers, Tunis and Spanish North African ports large quantities of iron ore were imported, amounting in 1917 to more than 1,000,000 tons, while from Algiers and Tunis, which together produce nearly half the world's output, were drawn all British imports of phosphate rock, payment, amounting to about £56,000 per month, being made in sterling. From Sicily was imported sulphur,[2] and from the Greek Island of Eubrœa, magnesite. The Salonica expedition was doubtless instrumental in saving this source of supply of that invaluable mineral from German hands. From Naxos came emery stone, of which the French Government had obtained control early in the war.[3] It was carried by the French to Marseilles, whence the British half share (as arranged between the respective Governments) was shipped to this country in British vessels. Zinc ore (silver lead) was imported from the mines of Laurium, and cotton from Egypt, while many raw materials came from the Near East *via* the Suez Canal.

The trade with the various Mediterranean ports was mostly in the nature of round voyages. Thus colliers bound for Genoa, Marseilles, and Barcelona would return with sulphur, magnesite, iron ore or phosphate rock. So great was the demand for tonnage in the Mediterranean trade that ships had to be withdrawn from the Karachi wheat traffic to carry munition cargoes from these nearer ports.

(*f*) The Near East and Far East.

From Abyssinia came rubber; from British East Africa asbestos, alcohol and lead; from the late German East Africa (after its occupation), mica in considerable quantities, and copper. India furnished large supplies of raw materials for practically all classes of munition manufacture, in addition to finished articles which were turned out in government and privately owned workshops.[4] Manganese ore, magnesite, chrome ore, copper and mica were the chief materials provided. India and German East Africa together produced three-fourths of the whole world's output of mica, upon which British supplies mainly depended. From India there came also shellac and wolfram, nuts, beans and oil seeds and rubber. Calcutta was the main source of shellac, which was

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[1] For a detailed account of Spanish ores *see* Vol. VII, Part II, pp. 26–31, and for the supplies from Switzerland, *see* Vol. II, Part VII.

[2] For a detailed account of sulphur and phosphate purchases *see* Vol. VII, Part IV.

[3] Vol. VII, Part III, Chap. XI.

[4] For an account of munition supply from India, *see* Vol. II, Part V.

largely used for varnishing the inside of shells. Cotton also figured largely among war imports to the amount of about £2,000,000 per annum, and from Ceylon came graphite, cocoa-nut oil and rubber. Payment was made in rupees, although difficulties arose as regards the exchange, owing to shortage of silver.

In consequence of the dangers of navigation the route round the Cape of Good Hope was more utilised than the direct passage through the Suez Canal, even in respect of cargoes from Bombay and Karachi. From the Far East supplies of lead, wolfram ore, molybdenite and tungsten came from Siam and Burma, through the port of Rangoon, whence also came timber and rubber. The Federated Malay States and Siam yield more than one-half of the world's supplies of tin.[1] From the Malay States rubber to the amount of 30,000 tons per annum was also imported, and tungsten to the value of about £850,000 per annum, payment being made in sterling. The trade with the Straits Settlements was largely linked up with that from the Dutch East Indies and Australia, the carrying being done as far as possible by the lines which operated before the war. The route round the Cape was the one most used, and the presence of Japanese war vessels in these and contiguous waters enabled the voyages to be maintained with comparative safety.

More important than the commodities which Japan supplied directly during the war was the naval aid she afforded in the protection of our shipping in Eastern and Pacific waters. Her aid to the Allies in the way of munitions was mostly given to Russia, *via* Vladivostock, in the early stages of the war. Of raw material she exported to Great Britain copper, spelter and silk waste. Freights from Chinese and Japanese ports ruled high throughout the war, rising to as much as £75 per ton. The sailings were few and far between, ships being chartered for the round voyages only about once a month, and then laden with various and, in some cases, low priced commodities. The Kaisha Maru line of steamers conveyed to these shores practically all the essential goods proceeding from Japan and China. From China there came, in addition to silk waste, antimony and lead. The Dutch colonies supplied tin as well as Borneo petroleum, which was particularly rich in toluol and was shipped direct to the Bristol Channel and Barrow-in-Furness.

(*g*) South and West Africa and Australia.

South Africa yielded copper, lead, asbestos, corundum and alcohol. From Rhodesia came chrome ore and rubber. From West Africa was imported alcohol ; from the Gold Coast bauxite,[2] rubber, nuts and seeds for oil, olive and other oils and manganese ores ; rubber was also brought from the Republic of Liberia and the Belgian Congo.

The conveyance of the very considerable bodies of troops from Australia and New Zealand imposed a great strain upon shipping capacity, and it was only with the aid of Japanese and United States vessels that munition materials could be brought from these distant parts. Australia sent copper, from the famous Mont Morgan Mines, spelter, wolfram, and manganese ore. She also supplied lead bullion, antimonial

[1] *See* Vol. VII, Part III, Chap. VII. [2] C.R.V./A./030.

lead, refined copper and spelter for the munition purposes of the Allies, and reserved the whole of her antimony, molybdenite and wolfram for the use of the British Government.[1] In the last year of the war shipments from these more distant countries had to be suspended on account of the shortage of tonnage.

(*h*) South America.

Of the South American republics the Argentine, Chile, Columbia, Ecuador, Salvador and Venezuela observed neutrality during the war. Bolivia, Peru, Nicaragua, Panama and Uruguay severed diplomatic relations with the Central Powers, while Brazil, Guatemala and Honduras became active belligerents on the side of the Allies. British imports of munitions materials from both the Atlantic and the Pacific States of South America were fairly extensive. Although imports from the Argentine were mostly in the nature of food, from Buenos Aires small parcels of wolfram were shipped from time to time, in addition to antimony which came overland to that port from Bolivia.

From Brazil came zirconium, rubber, antimony and ferro-manganese, most of the shipments of the latter going through the United States of America. Rubber was mostly shipped from Para. Imports of Brazilian manganese and rubber amounted in 1917 to $3\frac{1}{2}$ million pounds sterling. From Colombia came small amounts of platinum.

Bolivian shipments of antimony, tungsten, tin, copper and wolfram were chiefly made from the Chilean port of Arica and thence through the Panama Canal. The purchases of antimony amounted in 1917 to about £50,000 a month, and of tungsten to about £187,000 in the first six months of that year, the greater part being obtained through the French Government. Payment was made in sterling, and British imports from Bolivia doubled from 1916 to 1917. The chief British interest in South America, however, lay in Chile.[2] Her fine Pacific ports, Arica, Iquique, Autofagasta and Valparaiso afforded excellent loading facilities for the export of numerous raw materials essential to the manufacture of munitions. Her exports to Great Britain included nitrate of soda, copper, antimony, saltpetre and sulphur.[3] Chile holds the world's monopoly in nitrate of soda. It was shipped mostly from Iquique, the normal exports from which were about 650,000 tons annually.[4] Colliers taking out coal returned with cargoes of nitrate. In the critical year 1917 the diversion of tonnage to meet the needs of our Allies (notably France and Italy) was so difficult to arrange that the utmost endeavours were made to amass considerable reserves of this important mineral in the United States of America and thus to set free ships employed in the Australian wheat trade.[5]

The routes followed by ships clearing from Chilean ports were either through the Magellan Straits or *via* the Panama Canal, the latter being the voyage usually taken by vessels proceeding to United States

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[1] For a detailed account of munition supplies from Australia, *see* Vol. II, Part VI.

[2] C.R.V./C./068.

[3] 74/H.E.S./186.

[4] *See* Vol. VII, Part IV, Chap. III, and below, p. 16.

[5] C.R.V./C./068; C.R.V./W./1.

ports. The exports of nitrate of soda to the United Kingdom in 1917 were to the value of £6,500,000, and of antimony and tin £2,000,000. Payments were made in sterling to Messrs. Anthony Gibbs & Company.

Mexico provided lead, copper and zinc ore, while from the British West Indies were imported considerable quantities of alcohol.

II. The Department of Munitions Overseas Transport.[1]

(*a*) Formation of the Department.

The Ministry of Munitions had not been in existence for many months before the need for a department to deal with the overseas transport of materials became urgent.

In the early months of 1916 the tonnage problem was becoming serious, and Lord Curzon's Shipping Control Committee viewed the prospective shortage with considerable anxiety, urging the necessity for closer supervision over munition orders involving ocean transport. Freights were rising and unprecedented demands for tonnage were being made from all quarters, and the Ministry of Munitions, owing to the ever increasing munition programmes, had become an importer upon an enormous scale. The difficulty was increased during the first six months of the Ministry's existence owing to the fact that no demand for shipping space was made from the Department as a whole. Each branch applied independently according to its requirements, and in some cases large orders were placed abroad without due consideration of the question of freight. The Admiralty was overwhelmed with demands for tonnage from the various supply departments of the Ministry, and the use made of the tonnage available for munitions was unsatisfactory owing to the consequent overlapping and confusion. The Director of Transports (Admiralty) urged upon Mr. Lloyd George the desirability of a separate shipping department in the Ministry of Munitions, so that the increasing shipping demands of the Ministry might all pass through one channel, and the Department of Munitions Overseas Transport was formed in January, 1916, under Mr. (later Sir Robert) Burton Chadwick as Director.

At the end of 1916 the proportion of tonnage requisitioned by the State was less than one half of the whole, and the bulk of the liners were still licensed to trade in the accustomed routes. Within a few months of the Shipping Controller's appointment in December, 1916, practically the whole of the British ocean-going mercantile marine was brought under requisition at Blue Book rates,[2] and ships which had been trading with Australia and the Far East were transferred to the Atlantic routes.

(*b*) Functions of the Department and of the Shipping Priority Committee.

The Overseas Transport Department served as the liaison between the Ministry of Munitions, on the one hand, and Lord Curzon's Shipping Control Committee, and later the Ministry of Shipping,

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[1] Hist. Rec./H./2060/1 ; 2000/1 ; Hist. Rec./R./2060/25 ; 263/21(9). (Printed) *Weekly Report, passim.*

[2] *War Cabinet Report,* 1917, p. 107.

on the other. From September, 1916, all communications, written or oral, with the Admiralty on matters of transport went through the Director of Overseas Transport. The duties of the department as defined in February, 1916,[1] also included correspondence with other authorities concerned with overseas transport, and general assistance to importers of munitions or materials in respect of Ministry of Munitions contracts. In addition to these liaison duties the department gradually assumed executive powers in certain directions. For example, when a new iron-ore chartering scheme was introduced in the spring of 1916, the Overseas Transport Department became responsible for chartering the ore steamers, and appointed agents in the ports of discharge in the United Kingdom to accelerate unloading.[2]

From the formation of the department the Director of Overseas Transport prepared quarterly forecasts of the probable tonnage requirements of the supply departments of the Ministry ;[3] but, as the tonnage problem became more complex and the space available for munitions fell below requirements, it became clear that a special committee was needed to investigate the claims of the various departments before presenting the requirements of the Ministry as a whole to the Inter-departmental Tonnage Priority Committee. On 11 January, 1917, therefore, a Shipping Priority Committee was formed under the chairmanship of Mr. Burton Chadwick,[4] to collate and enquire into the demands put forward by the supply departments, their contractors, and sub-contractors, and to determine their relative urgency. Difficulties occasionally arose when goods waiting on the wharves were shipped in preference to detaining the ships until the arrival of the scheduled cargo, but on the whole the Shipping Priority Committee worked smoothly, and its services were especially valuable in the opening months of 1918, when the critical food situation reduced the allocation for munitions within the narrowest limits.

(*c*) Co-operation with the Allies.

In 1918, the principle of inter-Allied co-operation had so far developed that an Allied Maritime Transport Council was appointed which considered the relative claims of the Allied food programme as against the Allied munitions programme. The tonnage position had become worse for the Allies in 1918 because of the demands of the United States for shipping to convey troops and stores, and British overseas trade and the interests of outlying portions of the Empire were ruthlessly sacrificed to serve the common cause. Ships were taken from the longer voyages to the East and used for the Atlantic service, and the munition supplies of the Allies were treated from a common standpoint. British tonnage was freely used in the service

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[1] Office Memorandum No. 45 (29/2/16). Copy in Hist. Rec./R./263·032.

[2] Memorandum on *Discharge of Iron Ore Steamers at British Ports*, 1917; *see* below, p. 9.

[3] A.C. 89.

[4] The members were Mr. G. M. Booth (Vice-Chairman), Mr. W. T. Layton, Sir Cecil Graham, Sir Edgar Jones, succeeded by Lieut.-Col. Alan Burgoyne, Mr. P. Hudson and Mr. T. C. Hancock (Secretary).

of the Allies, ships were diverted to carry wheat for France and Italy, and every effort was made to send fresh supplies of shells and high explosives to Italy after the disasters of the spring of 1918.

III. Iron Ore Shipments.

By far the most important material imported for munition manufacture was iron ore, which occupied more than half of the tonnage allocated to the Ministry of Munitions, and was of vital importance to the supply of pig-iron and steel. Before the war the normal import had been 6,000,000 tons per annum, but it was estimated that at least 9,000,000 tons per annum were needed during the war.[1] Home supplies of iron ore were augmented by shipments from Spain, the Mediterranean ports and Scandinavia, and for the carriage of these important raw materials Great Britain depended largely upon neutral ships. The shortage of tonnage reacted seriously upon the supplies of iron ore, and as early as March, 1916, the requirements of the ironmasters far exceeded the supplies available.[2]

(*a*) Chartering of Steamers and Control of Freights.

Efforts to relieve the situation by securing additional tonnage from the French and Italian Governments met with only limited success. One of the principal difficulties was the question of freights, which had risen—in the case of shipments from the Mediterranean and the Bay of Biscay—from 8s. 6d. per ton in 1913 to 24s. 6d. and 26s. 6d. per ton, respectively, in 1915. This became of particular importance in March, 1916, when the Government decided to fix maximum prices for pig-iron and iron ore, as the price of the latter varied with the rate of freight. It was agreed, therefore, that a standard freight rate should be drawn up, and that the Ministry should be responsible for all freight in excess of this parity rate, and for demurrage due to congestion. The duty of superintending the chartering of iron ore steamers was placed in the hands of the Director of Overseas Transport, who dealt with shipment of Spanish, Swedish and Mediterranean iron ore, Raasay iron ore, Welsh limestone for Scottish ironworks, phosphate rock and calamines. Agents were appointed in the iron ore ports of the United Kingdom to give advice and to accelerate the rate of discharge. In March, 1917, this work of chartering was transferred to the Shipping Controller, but the Iron Ore Section of the Overseas Transport Department continued to deal with steamers after they were chartered and maintained its agencies at the ports.[3]

The aim of the Government in controlling iron ore freights was to prevent internal competition between charterers, which had resulted in unduly inflated rates of freight. The parity rate fixed by the Ministry of Munitions was 17s. per ton, and this might have been further reduced had not there been the fear of driving neutral shipping out of the trade. All freight in excess of this parity rate was paid by the Ministry of Munitions, and, until September, 1916, the Overseas Transport

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[1] M.O.T. 654.
[2] For further details on this subject *see* Vol. VII, Part II, Chap. II.
[3] *See* Vol. VII, Part II, Chap. VI.; A.M.2/265.

Department found no difficulty in securing ample tonnage at the controlled rate. From October onwards the situation changed. Submarine activity in the Bay of Biscay had considerable effect in keeping neutral tonnage out of the trade. The Director of Overseas Transport was obliged to ask that greater pressure should be brought to bear on steamers employed in the French coal trade, in order to supplement the supply of tonnage for loading at Bilbao ; and in November, 1916, the situation was reported to be serious.

The difficulty was further increased by the action of the French and Italian authorities in supplementing their coal supply by chartering steamers from neutral and, to some extent, from British owners on time contracts. Many of these steamers returned in ballast and the owners were no longer willing to contract with the Overseas Transport Department for the single journey at the limited rates fixed. Efforts were made to come to an agreement with the Italian Government that tonnage used to carry coal to Italy should convey ore on the return journey from the Mediterranean, and the Italian authorities eventually undertook to supply 125,000 tons of Italian tonnage per month for the transport of ore. By the terms of the agreement Italy was allowed to offer 180s. for the round voyage, in the proportion of 100s. out with coal and 80s. home with ore, including war risk insurance on the hulls.

(*b*) Effects of increased War Risks.

In December, 1916, the supply of tonnage for iron ore proved quite inadequate to meet the demand. The decrease in tonnage was mainly amongst neutral steamers, partly because of the high premiums required for war risk insurance owing to increased submarine activity, partly because of the unwillingness of Spanish crews to undertake the more dangerous voyage from Bay ports to the United Kingdom. The Government scheme of war risk insurance for neutral steamers was intended to overcome the tendency of neutral shipping to leave the more dangerous routes. At the same time, early in 1917, increased rates were scheduled for neutral ships on time charter to British or French charterers conveying ore. These were as follows :—

Vessels discharging at—	*Proceeding to—*	*s.*	*d.*
S. Nazaire, Rochefort or adjoining ports.	East Coast	40	0
	North West Coast	34	6
	Bristol Channel	30	0
Bordeaux	East Coast	34	0
	North West Coast	28	6
	Bristol Channel	24	0
Bayonne	East Coast	32	0
	North West Coast	26	6
	Bristol Channel	22	0

Ore freights for neutral steamers from Mediterranean ports were also increased, but no advances were made in the case of British tonnage which carried at government rates.

(*c*) Payment of Iron Ore Freights.

On 5 June, 1917, a new system of payment for iron ore freights was arranged by the Overseas Transport Department with the concurrence of the Finance Branch and the Ministry of Shipping. By this

arrangement, the ships' agents at the port of discharge collected the parity rate of freight from the receiver of the cargo, the excess over the parity rate being paid by demand draft issued by the Overseas Transport Departments' agents at the various ports and drawn on the Paymaster-General. This system was found to work well and helped to relieve the serious burden thrown upon the ironmasters, a number of whom stated that they were unable to continue the payment of the high freights then demanded by neutral ships.

(*d*) Difficulty of Transporting Ore to East Coast Ports.

The supply of tonnage from the Mediterranean to the ports on the West Coast of Great Britain was fairly satisfactory in the spring of 1917, but great difficulty was experienced in finding steamers for the East Coast, owing to the greater submarine risks involved in the passage of the English Channel. During the same period the scarcity of shipping offering for charter from the Bay ports was very marked, for several weeks in succession not a single Spanish steamer coming forward. Even the increases conceded in the ore freight rates did not make more tonnage available for the East Coast.

(*e*) Reduction of Tonnage Allocation in 1918.

During the autumn of 1917 the ore imported from Spain and the Mediterranean averaged 115,000 tons a week, but a drastic reduction in the tonnage allocated for 1918 was rendered inevitable by the continued submarine losses, the food shortage in Great Britain, France and Italy, and the diversion of ships to the transport of American troops. On 2 November, 1917, the Ministry of Shipping reported that the estimated importing power of the ships available for 1918 would be 8,000,000 tons less than for the preceding year, and a committee was appointed, with Lord Milner as Chairman, to arrange for drastic reductions in the allocation to all Departments of State. As a result of these and other reductions, the Ministry of Munitions was called upon to reduce its imports by 5,000,000 tons, a measure which very seriously affected the importation of iron ore. The imports finally made on munitions account in 1918 amounted to nearly 12,000,000 tons, and of this amount more than half was allotted to iron ore, owing to its vital importance in the manufacture of munitions. The actual figures of the proposed allocation for 1918 show the relative importance of the different imports and were as follows[1]:—Iron ore, Spanish and Mediterranean (5,400,000), other iron ore (660,000), shell steel (500,000), finished shell, guns and small arms ammunition (650,000), Swedish iron (100,000), general steel (U.S.A.) (150,000), nitrate of soda (550,000), pyrites (820,000), manganese ore (360,000), copper (220,000), spelter and zinc concentrates (70,000), aluminium (12,000), bauxite (55,000), lead (150,000), magnesite (60,000), other non-ferrous metals (120,000), T.N.T. and propellant (80,000), other explosives (50,000), aircraft supplies (12,000), railway material (12,000), mechanical transport (43,000), machine tools (30,000), agricultural

[1] Hist. Rec./R./2060/25.

machinery (50,000), sulphur (70,000), lubricating oil (300,000), and phosphate rock (300,000). The total allocations thus amounted to 10,824,000 tons.[1]

In the summer of 1918 tonnage became more plentiful, and in the third quarter of the year the ore imported averaged 130,038 tons per week and the steamers chartered 41. Besides the ore brought from Spain and the Mediterranean, supplies were also obtained from Scandinavia, and during August shipments of Narvik ore amounted to 76,200 tons.

IV. North American Shipments.

(*a*) General Imports.

Next in importance to the shipment of iron ore ranked the importation of finished munitions and raw materials from North America. During the greater part of 1915, shipments of munitions from the United States were managed by Messrs. Lunham and Moore, who acted as shipping agents for the Ministry. Early in 1916 the American railroads and docks proved unequal to the tremendous increase in traffic resulting from the war. There was great congestion in the ports from which munitions were shipped, and at New York, in February, 1916, the accumulated freight amounted to 20,000 tons and was reported to be increasing.[2] Tonnage placed at the disposal of the French and Italian authorities was often wasted by ships travelling empty from the Southern ports to New York, and by awaiting special cargoes. Representations were therefore made to the Admiralty to make direct disposition of any ships in port to the best advantage, and also to send instructions to Messrs. Lunham and Moore to divert the traffic, as far as possible, from New York to the more Southern ports.

As has been seen elsewhere,[3] Sir Ernest Moir's organisation in America set up a special section to supplement Messrs. Lunham and Moore's work. The problem was dealt with on a broader scale in April, 1916, when a section of the Overseas Transport Department was formed to control the shipment of munitions from Canada and the United States. The section examined the claims of Ministry contractors for freight space, and dealt with firms requiring assistance in the import of goods from America. Each case was carefully investigated to ensure that shipping space was available, and certificates were issued where necessary for the refunding of the difference between market and government rates. The diversion of traffic from New York to other ports proved completely successful and, until November, 1916, delays in shipment were usually due to railroad breakdowns, labour troubles or other temporary causes and any arrears were made up in the following month. Some idea of the tonnage required and the number of ports used may be seen from the details of tonnage on hand in April, 1917. There were then at Boston, 4,080 tons, New York, 4,966 tons, Philadelphia, 17,097 tons, Baltimore, 16,741 tons, Newport, 20,805 tons, Norfolk, 19,982 tons, Brunswick, 7,888 tons, New Orleans, 12,350 tons, Galveston, 26,029 tons, Mobile, 20,010 tons, Portland, 3,098 tons, and at Savannah, 8,877 tons.

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[1] For the methods used in preparing the Department's shipping estimates, *see* Vol. IX, Part I, Chap.IV.

[2] 94/Gen./416.

[3] Vol. II, Part III, Chap. IV.

In November, 1916, serious difficulties again arose owing to the shortage of tonnage, but these were overcome after the appointment of the Shipping Priority Committee, in January, 1917. It then became possible to allocate the available tonnage amongst the various departments to the best advantage, and to assist private contractors who were also seriously affected. Thus, in September, 1917, when an order for phosphate rock was placed in Florida, the Shipping Priority Committee was asked to agree to a reduction of shell forgings and steel to make the shipment possible; and again, in 1918, the Inter-departmental Priority Committee decided that agricultural machinery should have the same priority as cereals, taking precedence over all other classes of goods.

As the submarine campaign became more ruthless the lack of tonnage increased, until, in October, 1917, the Shipping Controller allocated only 200,000 tons for the month to the shipment of munitions from the United States, while the demands of the supply departments exceeded 238,000 tons. Owing to shortage in the wheat harvest, additional space became unexpectedly available, and shipments amounting to 225,448 tons were actually made, apart from an additional 29,714 tons which was allocated to locomotives, lumber and phosphate rock. But in November the shortage of tonnage again became very marked; the space provided for the transport of munitions from the United States being only 161,265 tons, while the estimated requirements of the Ministry were some 213,000 tons monthly. The result was congestion on the railroads and in the American ports, until by the end of the month there were 288,200 tons of war material awaiting shipment. Heavy shipments of munitions were made from Canada as well as from the United States, the Canadian total for November, 1917, being 41,974 tons. The tonnage problem was regarded by the Imperial Munitions Board with increasing anxiety, and an attempt was made to secure additional tonnage by using armed cruisers for carrying munitions, but the plan was not completely successful.

During the spring and summer of 1918, the scarcity of tonnage was severely felt, and, in August, 1918, the Ministry was informed that the Shipping Controller was not likely to have more than 150,000 tons available to cover shipments from both Canada and the United States, and the supply departments must rely on imports from America as little as possible. In case additional tonnage became available owing to non-arrival of cereals the Ministry were asked to get as much pig-iron and shell steel to the seaboard as possible before winter set in, so that the congestion of the railways of the previous year might not be repeated. The improvement in the war situation, however, had an immediate effect upon the tonnage problem, and much heavier shipments of munitions and steel forgings were made from the United States and Canada in the autumn than had been allowed for in the provisional scheme drawn up by the Ministry earlier in the year. With the signing of the Armistice steps were taken to reduce the import of munitions from America to a minimum, and all available ocean tonnage was used for foodstuffs, unfilled space being reserved for pig-iron, copper, spelter and other commodities most needed in

Great Britain. The Overseas Transport Department adapted itself to the changed conditions, and assisted private firms in the transference of their activities from war material to the establishment of trade on a peace basis.

Throughout the war period the heavy war risks inevitably reacted upon the rate of freight, forcing up the market rate on shipments from the United States until it reached unparalleled figures. On 1 January, 1918, the government rate of freight for war material carried on liners was increased from 40s. to 82s. 6d. per ton, and a considerable amount of munitions and materials was shipped on private account at this rate as part of the tonnage allotted to the Ministry. At the same time the market rate was $650 per 100 lb. or about £30 per ton, the cost of freight in many cases amounting to more than the value of the goods.

(*b*) American Lubricating Oil.

Practically the whole of the lubricating petroleum oil used in this country was imported from the United States. Although the consumption of this oil in Great Britain had increased considerably owing to the war, the rate of import had not increased proportionately. The tonnage available was small, tank steamers had been requisitioned by the Admiralty, and the position was complicated by the unpopularity of lubricating oil as a cargo. The stocks, which had been very considerable at the outbreak of war, had been gradually reduced, until in April, 1916, there was less than a month's supply in reserve in the country.[1] The Board of Trade returns for 1915, showed that 76,790,075 gallons of petroleum lubricating oil were imported during the year, and with the greatly increased consumption at least 95,000,000 gallons would be needed in 1916[2]; yet unless the rate of import of the first quarter of the year were considerably augmented, only some 68,000,000 gallons would actually be brought into the country. As a consequence, the Shipping Control Committee and the Board of Trade were asked to reduce non-vital imports in favour of oil.

Early in 1916 the Anglo-American Oil Company issued a circular, stating that, owing to the requisitioning of their ships by the Government, only 60 per cent. of their contracts could be fulfilled, and oil dealers feared that it would be impossible to obtain supplies. The Director of Overseas Transport called a meeting of representatives of the oil trade, and a committee was appointed to advise the Ministry on the importation of lubricating oil. From this time the department arranged for the carriage and allocation to importing firms of all lubricating oil coming to this country, which amounted to about 24,000 tons per month. The attempt to improve the stocks in the United Kingdom was so far successful that on 31 December, 1916, there were about 66,000 tons in store; but in the summer of 1917 submarine losses again reduced the tonnage available. In July, 1917, only 13,000 tons of lubricating oil and wax were sent from America. There was some improvement in August and September, but the

[1] D.D.G.B. 196. [2] *Ibid.*

position again became serious in October, when the Shipping Controller reduced the tonnage allocation by 6,000 tons per month. Efforts were therefore made to restrict the export of paraffin wax, 50 per cent. of the Scottish production having been hitherto exported; and in October, 1917, the total ration for the next twelve months allowed to Allied countries was fixed at 5,000 tons.

Difficulty also occurred over the insurance of cargoes, as oil was sometimes shipped from New York at the government rate of freight in American owned vessels. As a result, the importers had either to pay as much as 30 per cent. in insurance or send their cargoes uncovered. In July, 1917, the rate of freight on shipments of lubricating oil and paraffin wax from the United States to Great Britain in government space increased from £4 to £6 per ton. In the summer of 1918 it was again necessary to raise the rate of freight, which became £12 per ton from August onwards.

V. Shipment of Petroleum Products and Miscellaneous Materials.

The provision of all kinds of petroleum products, in addition to lubricating oil, was very largely a matter of tonnage. Accordingly, the regulation of petroleum supplies rested for some time, *i.e.*, between August, 1916, and April, 1917, with a sub-committee within the Overseas Trade Department, with representatives from other Departments concerned. This body was known as the Committee for the Regulation of Petroleum Supplies and dealt with all questions of stocks, tonnage and supply, until the appointment of the six leading petroleum importers as a Pool Board, in April, 1917.[1]

The scarcity of fuel oils was even more serious than the question of lubricating oil. In November, 1916, forty-four controlled firms employed in making munitions used fuel oil, their consumption amounting to 50,000 tons per annum. The shortage of tank steamers increased the difficulty of obtaining adequate supplies, and when, in January, 1917, the Admiralty were unable to replace four tankers which had been torpedoed, the position became critical. Efforts to obtain tankers from neutrals met with no success, and an attempt was made to meet the difficulty by bringing oil over in ordinary double bottoms, but it was not an unqualified success. Upon the entry of the United States into the war, the Ministry of Munitions made urgent representations to the Admiralty to obtain tankers from this source, pointing out that in no way could the United States render more valuable help to the Allied cause. The measures taken for the control of these supplies are described elsewhere.[2]

Although iron ore, fuel and finished munitions occupied the greater proportion of the tonnage allocated to the Ministry of Munitions, a large quantity of war material which did not fall under any of these categories was imported, as has been shown above.[3] Of the

[1] The members of this committee were: Mr. Burton Chadwick (Chairman), Mr. E. W. Rowntree (Board of Trade), Mr. B. A. Kemball Cooke, Mr. J. C. Clarke (Admiralty), Mr. A. Duckham (Ministry of Munitions), Mr. S. N. Rice (War Office), Mr. E. H. Fry (Secretary). (HIST. REC./H./2060/1). For its establishment and work *see* Vol. VII, Part III, Chap. X.

[2] Vol. VII, Part III, Chap. X.

[3] *See* above, pp. 1–7.

imports dealt with under this section, nitrates ranked first in importance. Ample supplies were obtainable from Chile, even for the war demand which was five times as great as in peace time; but owing to the length of the voyage and the steady rise in freights, the shipping question became an almost insuperable difficulty as the war continued. Ultimately the needs of the Allies became so pressing that steamers sailing with cargoes for Great Britain were from time to time diverted to France and Italy, so that immediate relief could be afforded. In the final stages of the war the position became much improved. Larger cargoes were sent from Chile with greater regularity, and the figures for August, 1918, showed that the sailings of nitrate of soda from Chile under government contract were 41,125 tons.[1]

The dependence of the Ministry of Munitions upon the outlying possessions of the British Empire for raw materials was very great, and a table of imports for January, 1917, gives some idea of the magnitude of the task which the Overseas Transport Department was called upon to face in this respect.

Imports, January, 1917 :—	*Tons.*
Lead (Rangoon and Australia)	12,674
Rubber (India and Australia)	11,769
Tungsten ores (Rangoon and Australia)	650
Copper (Australia)	3,395
Manganese ore (Australia and India)	11,769
Silk waste (India and Far East)	218
Magnesite (India)	1,240
Chrome ore (India)	646
Mica (India)	273
Cotton waste (India)	4,831
Shellac (India)	196

VI. Work at the Ports.

(*a*) Overseas Transport Organisation.

One important branch of the work undertaken by the Overseas Transport Department was the supervision of steamers in port. At the beginning of the war much time was lost and tonnage wasted owing to the congestion at the docks. Steamers lay two or three days awaiting a berth, further time was lost in unloading as insufficient labour was obtainable, and the goods when unshipped piled the wharves until railway wagons were forthcoming.

To overcome these difficulties, which were especially noticeable in the case of iron ore cargoes, which needed experienced dockside labour to unload them, agents, who were usually experienced shipping firms, were appointed in the ore ports of the United Kingdom to accelerate the rate of discharge and lessen the charges for demurrage. Agents were appointed at the following ports :—Glasgow, Newport, Cardiff and Barry, Newcastle (Tyne Dock), Barrow and Heysham, Middlesbrough and Stockton, Garston, West Hartlepool, Maryport, Whitehaven and

[1] *See* above, p. 6. For a detailed account of supplies of Chile nitrate, *see* Vol. VII, Part IV, p. 55.

Workington, Ardrossan and Ayr, and Swansea, Port Talbot and Briton Ferry. The duties of the firms appointed as special agents by the Overseas Transport Department were to report on the progress of work in each ship, on the conditions of port labour or any other matter relating to the discharge of cargo. They worked in co-operation with the Port and Executive Committee, the Director of Inland Transport, the dock authorities, and with all firms interested in the cargoes, and advised the Director of Overseas Transport where improvements could be made and suggested how they could best be carried out. The agents were also responsible for adjusting the difference between the market rate of freight and the parity rate for iron ore cargoes. In return for these duties they received a commission, varying from £1 to £3 for each steamer according to its capacity, the higher amount only being paid on steamers carrying 5,000 tons and upwards.

Dockside labour became a pressing problem in the closing months of 1916, as the Army had made heavy claims upon the best type of worker. In May, 1916, the Government had made a tentative experiment in recruiting some 600 men as a Transport Workers' Battalion[1] to be employed at the docks when, in the view of the local authorities, there was a shortage of civilian labour. In November, 1916, as the result of representations from the Director of Overseas Transport, the number of Transport Workers' Battalions was increased and their sphere of work extended until by November, 1918, they numbered 14,887 men employed in 134 ports, iron works, canals, etc. Members of Transport Workers' Battalions were employed at all the iron ore ports in 1917, and a great improvement in the rate of the daily discharge of ore steamers became evident. This organisation of dock-side labour was supplemented by the introduction of mechanical grabs,[2] and some comparison between the conditions in 1916 and those in 1917 may be seen from the following table,[3] which relates to the discharge of iron ore in eleven of the largest ports :—

	July to Dec., 1916.	Jan. to Sept., 1917.	Difference per cent.
Average size of steamers	3,125 tons	3,681 tons	+ 18
Average time awaiting discharge ..	2·15 days	1 day	— 54
Average time discharging	6·90 days	4·18 days	— 39
Average time in port	9·06 days	5·21 days	— 42½
Average discharge daily	453 tons	776 tons	+ 71

It was further calculated that the number of days of ships' time saved by the reduction of time spent awaiting discharge was 1,178 and that by the increased rate of discharge 2,978. The total number of days of ships' time saved was 4,156. When the convoy system was adopted in 1917 for Transatlantic and Mediterranean voyages, the difficulties of discharge were increased as the ships arrived in fleets instead of singly, and the interval between arrivals was extended. In a short time, however, with the aid of the Transport Workers' Battalions,

[1] A Liverpool Dock Battalion had been formed as early as 1915.
[2] This was one of the duties of the Inland Transport Branch, *see* below, p. 25.
[3] (Printed) *Weekly Report*, No. 115, V. (27/10/17).

labour adapted itself to the new conditions and the rate of discharge was not materially affected.

Some idea of the magnitude of the task which confronted the Overseas Transport Department may be gained from the table of imports[1] brought into the country for munitions purposes. The imports on munition account averaged 11,750,000 tons per year, and even in 1918, when tonnage was diverted for the transport of troops from the United States and cereals were given absolute priority over all other forms of war materials, the total import of munitions exceeded that of 1915 by 1,300,000 tons. Such a result in the face of grave difficulties could only be attained by efficient organisation, and it was largely due to the efforts of the Overseas Transport Department that during the most critical period, the utmost carrying power was secured from the tonnage available.

(*b*) Port Forwarding.[2]

Until April, 1917, responsibility for receiving and checking shipments at port and for despatching the materials received to their proper destinations rested with a number of different authorities. Various sections of the Ministry appointed special officers for the purpose or employed the steamship companies as agents. Despatching from the United States of America was undertaken by a single agent, Messrs. Lunham and Moore, working under contract with the Admiralty at a commission of 6d. per ton. In some instances the War Office embarkation officer at a port undertook these duties.

A special Port Forwarding Department of the Ministry of Munitions was formed in April, 1917, under Mr. W. T. Potts, J.P., to co-ordinate the work of these miscellaneous agencies. The department took over responsibility for agents at Liverpool, Manchester, Glasgow, Hull, Bristol, Cardiff, Plymouth and Portland, and also became responsible for receiving, decoding and distributing cables concerning shipments, not only for the Ministry of Munitions but also for several other Departments of State. Responsibility for handling munitions materials at port was transferred from the military embarkation officers to the Port Forwarding Department's officials during the summer of 1917. In August of that year the department opened an office for receiving and despatching imported fuses and other munitions arriving from overseas. In the following September the munitions work of the embarkation officer at the Port of London was taken over. The handling of shipments of complete gun ammunition was, however, reserved to the military authorities in view of the peculiar risks involved.

During two years ending on 1 April, 1919, the Port Forwarding Department dealt with 3,980 ships' cargoes amounting to nearly 5 million tons of steel, shells, machinery, explosives and all kinds of miscellaneous materials.

The activities of the Overseas Transport Department and the Port Forwarding Department in regard to expediting the discharge of cargoes and despatching them to destination were supplemented by the work of the Inland Transport Department, as will appear in the chapter which follows.

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[1] Appendix. [2] Hist. Rec./H./2062/1.

CHAPTER II.

INLAND TRANSPORT.[1]

The extensive manufacture of munitions and the increased requirements of the Army and Navy threw upon the railways additional traffic to be handled by a largely decreased staff. Further, the shortage of shipping previously engaged in the coasting trade diverted a large tonnage of traffic which would otherwise have been seaborne. The general shortage of labour and materials caused delay in repairs, and the supply of new rolling stock and materials eventually became a serious problem.[2] It became necessary to arrange for the partial pooling of railway wagons, to cut down travelling facilities and to supplement railway by road transport. Motor lorries and light cars were bought or hired by the Ministry, and arrangements were made for the fuller utilisation of privately owned motor vehicles. As a result the whole of the government traffic was handled, and it never became necessary to decide whether inland transport of the nation's food stuffs should take precedence over war materials or *vice versa*.

I. The Ministry's Organisation for dealing with Inland Transport.

(*a*) Central Organisation.[3]

The vastly increased projects for shell manufacture which accompanied the formation of the Ministry of Munitions in the summer of 1915, intensified the need for a centralised organisation to deal with the movements of materials and semi-manufactured or completed munitions. In September, 1915, therefore, a Forwarding and Delivery Branch (C.M. 8) was formed to be the medium of communication on transport matters between the various contract and supply sections of the Ministry of Munitions and the War Office, the Railway Executive Committee, railway companies and shipping agents. Its duties, as set out on 1 October, 1915, included the working of munition traffic through the ports and arrangements for the delivery of completed munitions; but these functions were never actually transferred. The branch confined its activities to communicating with the War Office, the Railway Executive Committee and the railway companies on questions of special services, transit facilities, siding accommodation, etc.; and in dealing with special transport problems. Minor difficulties in great variety were dealt with as they arose, and from

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[1] A more detailed account is filed in Hist. Rec./H./2020/2.

[2] An account of the difficulties and the steps taken with regard to the supply of rolling stock is given in Vol. XII, Part V.

[3] M.I.T./S./2463.

October to December, 1915, considerable extensions in the functions of the branch took place. The issue of various certificates which had been introduced to give priority of acceptance for urgent government traffic, the conveyance of empties or the granting of permission for the, transit of explosives by passenger train were transferred from the Contracts Branch. The section was also entrusted with the preparation of statistics for the Railway Executive Committee, showing the approximate tonnage of munitions traffic which the railway companies would be required to convey. Numerous applications were received daily from branches of the Ministry, controlled firms and other sources, relative to the expediting of urgent consignments, difficulties arising out of traffic restrictions and wagon supply, inadequate cartage facilities and other questions of a general character, which continued to increase as the section became more generally known.

The scope of the section's work was further extended in January, 1916, when it was made directly responsible to the Director-General of Munitions Supply. Among the new tasks undertaken during that year was the provision of facilities for conveying workers to and from national factories and controlled establishments. A special investigation was made into the working of tank wagons, on behalf of the Explosives Supply Department, and the section became responsible for the fulfilment of certain conditions which were regarded by the Railway Executive Committee as essential to the successful handling of the increased traffic anticipated in the Ministry's forecasts. These and other duties were thenceforward performed by the section for all departments of the Ministry, and on 29 February, 1916, its designation was altered to "Munitions Railway Transport Section" (M.R.T.). At the same time, its duties as modified by experience were formulated as follows :—

> "All correspondence with the Railway Executive Committee and with the Port and Transit Executive Committee will be conducted by this Section, as well as all headquarters correspondence with the Railway Companies, except so far as special arrangements may be agreed.
>
> "The Section will deal with transit facilities for Munition Workers, whether by rail, tram or road vehicle, and also with questions of inland transport generally, so far as these affect, or may relieve, rail transport."[1]

As the responsibility of the section for work in regard to motor and canal transport increased it became desirable to change the style of its name. Accordingly, from October, 1917, onwards, it was called the Munitions Inland Transport Branch (M.I.T.)[2]

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[1] The activities of the department in regard to providing additional facilities for the transport of munition workers have been described in detail elsewhere. *See* Vol. V, Part V, Chap. V.

[2] This title has been adopted throughout to avoid confusion. General Memorandum, No. 38.

Early in March, 1916, when an increase in the output of heavy shell became urgently necessary, arrangements for giving special transit facilities to the various component parts were left with the Railway Transport Branch. This necessitated the working out, with the Railway Executive Committee and the companies, services between certain points, the issue of priority certificates, arrangements for conveyance of small consignments by passenger trains and the diversion of short-distance traffic from rail to road. Similar arrangements were subsequently necessary for other special requirements. About this time the section also became responsible for watching the use of motor lorries which had been obtained by firms on priority certificates, granted upon condition that the vehicles should be used only for munitions traffic or other work of national importance.[1] Since rail and road transport were so closely allied it was decided at the end of March, 1916, to make the Inland Transport Branch responsible for the use of private cars for Ministry officers, and the provision of motor lorries for the conveyance of munitions.

Up to May, 1916, the work of the section had thus been continually increasing, thenceforward little or no further development in its functions occurred beyond some instances of late date, in which assistance was rendered to Departments other than the Ministry of Munitions, as, for example, to the Ministry of Food,[2] to the Board of Agriculture in regard to fertiliser traffic and to the Coal Mines Department. By May, 1916, sections had been set up at headquarters to deal with the following phases of transport work (1) railway and canal transport; (2) railway transport permits; (3) traffic regulations at factories and stores; (4) railway rates, rules and regulations; (5) sidings and new works; (6) transport of munition workers; (7) road transport; (8) staff, equipment and registry.

(*b*) LOCAL ORGANISATION.[3]

From the first, the regulation of munitions traffic involved much local investigation and action. Travelling inspectors were appointed at headquarters, and an experiment was made in October, 1915, in developing an organisation in the various munitions areas by the appointment of a Transport Officer at Birmingham to deal with transport questions for that area. The appointment proved successful, as not only was the transport officer of value to headquarters for local enquiries and other special matters requiring watching or investigating in the area, but also to the local munitions establishments and railway companies. The necessity for local enquiry was meantime growing beyond the power of the existing number of travelling inspectors. Accordingly, during January, 1916, transport officers were appointed in two other of the local munitions areas, *viz.*, at Leeds for Area 3 and at Manchester for Area 2. As the local work of munition production increased this system was extended and local officers gradually replaced

[1] Vol. XII, Part IV, p. 32. [2] M.I.T./Gen./969.
[3] M.I.T./A./1219.

the travelling inspectors from headquarters, until transport officers had been appointed in seven areas, with assistants in ten sub-offices as shown below :—

Area.	Transport Officer.	Sub-Offices.
1	Newcastle (July, 1916) . .	Middlesbrough (Oct. 1917).
2	Manchester (Jan., 1916)	Liverpool (July, 1916), Carnforth (Dec., 1916), Whitehaven (July, 1917).
3	Leeds (Jan., 1916) . .	Sheffield (April, 1916), Bradford (Nov. 1917).
4	Birmingham (Oct., 1915)	Coventry (Jan., 1918), Lincoln (Jan., 1918), Nottingham (April, 1918).
5	Cardiff (June, 1916) . .	—
6	Bristol (March, 1917) . .	Southampton (Sept., 1918).
7	London (Oct., 1916) . .	—

The dates in brackets indicate the date of first appointment.

The transport officers were responsible for notifying the railway companies of the respective urgency of different classes of traffic, for dealing with the detention and use of wagons and stores, and generally for watching munitions traffic and investigating cases of congestion. They supervised the operation of motor traffic controlled by the Ministry, and dealt with local questions arising from rates and the classification of goods, particularly of explosives. They advised on technical questions relating to railway matters, submitted to headquarters a general weekly review of the railway position in their area and kept in close touch with the local Area Offices on matters relating to railway traffic. By special arrangement at Newcastle, where shipments of munitions cargoes were spasmodic, the transport officer at that port also undertook responsibility for the discharge and forwarding of munitions from that port on behalf of the Port Forwarding Authority.

Transport arrangements of a special character were established in Scotland. The transport officer for Scotland had been appointed by the Director of Munitions in Scotland before the establishment of the Inland Transport Branch of the Ministry in September, 1915. The functions of this officer were not restricted to inland transport, but included questions affecting facilities at the docks, discharge of vessels, labour questions and other matters directly or indirectly affecting transport generally. From August, 1916 to November, 1918, the government stores which this officer was responsible for discharging and forwarding were received from 414 ships, with an approximate tonnage of 520,000 tons. The highest number of ships and tonnage dealt with in any one month was in November, 1918, when 25 ships arrived with 38,000 tons. The chief material to be handled was iron ore, and in the year ending October, 1918, 345 ships containing 1,329,202 tons of ore were discharged from the Glasgow docks.[1]

[1] The Transport Officer was responsible to the Director of Overseas Transport for this work.

As a result of the work of the transport officers many improvements were effected. Thus, for example, arrangements were made for a regular daily supply of pig iron from Middlesbrough to Scotland, considerable economies were secured in wagon usage and demurrage was reduced in the case of one large firm from £16,000 in 1915 to 4s. 6d. in 1918. Much work was also done by the local officers in diverting short distance traffic from rail to road or canal.[1]

II. Some Administrative Questions.

It will have appeared from what has already been related that the work of regulating munitions traffic was of a very miscellaneous character. The action taken varied with changing circumstances; but it should be of value to record some of the more important methods employed.

(*a*) Transit Permits.[2]

The question of priority between different classes of traffic was one of peculiar importance. Prior to the institution of the Ministry of Munitions an arrangement existed whereby priority in regard to railway conveyance was given to urgent government traffic by the use of an adhesive label or special permit which was marked :—

"Urgent for {Naval / Military} Service."

After the outbreak of hostilities the increase in munitions traffic led to an indiscriminate use of these labels, and in January, 1915, a new scheme of priority was introduced. Goods were divided into four classes and treated accordingly. Class 1 consisted of consignments of extreme urgency necessitating special train working; Class 2 of urgent naval or military traffic, or exceptionally urgent traffic passing between manufacturers for war purposes; Class 3*a* of ordinary naval and military traffic consigned to government establishments, and Class 3*b*, urgent munitions traffic from firm to firm. In the case of Class 2 traffic, orange coloured certificates (Form A) were issued to consignors for pasting on the consignment, and the railway companies then labelled the trucks containing such goods with a No. 1 Truck Label. In the case of Class 3*b* traffic, a Form B certificate was used which entitled the goods to a No. 2 Truck Label. Another certificate (Form D) was subsequently introduced to secure priority for empty packages on government account. This certificate system was of great assistance in expediting urgent ministry traffic.

Regulations for the conveyance of explosives, inflammable liquids and liquefied gases on government account were formulated by the Railway Executive Committee, and two certificates were issued to meet special cases. Certificate X was used where the consignment exceeded the amount permitted to be carried by goods train, and Certificate Y, when the consignment was for conveyance by passenger train or railway companies' steamboat.

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[1] *See* below, pp. 31–33. [2] C.M.8/80152.

(*b*) Free Conveyance of Munitions Traffic.[1]

At the time of the institution of the Ministry of Munitions no arrangements existed for the free carriage by rail of munitions traffic conveyed on account of the Government, although a limited practice was in operation in regard to War Office and Admiralty traffic, where military or naval authorities were both senders and consignees. This gave rise to considerable difficulty, and in the autumn of 1915 a project was set on foot for introducing some form of " carrier's note," similar to those used by the War Office and Admiralty, for the carriage of munitions between government stores and factories.[2] The proposal was, however, held in abeyance until February, 1916, and it was not until 15 May, 1916, that the Railway Executive Committee agreed in principle to the free carriage of Ministry of Munitions traffic. It was then decided that this should be limited to the cases where the Government was responsible for the carriage charges, and arrangements were made to safeguard the interests of the railway companies by the use of " free transit notes," bearing references to the Ministry's " advice notes," " issue warrants " and contract numbers, by a careful checking of weekly statements and by empowering the companies to examine the contents of any packages.[3] The Irish railways were excluded from this system until they came under government control in February, 1917. The system of free transit for munitions traffic operated from 24 August, 1916, and in the following September it was extended to cover empty packages. From November, 1916, onwards the Manchester Ship Canal Company, although not a controlled railway company, accepted the free transit notes of the Ministry. Not only did the adoption of the system of free transit notes lessen the clerical labour, but it also became a means of expediting munitions traffic, since it served to denote the character of the goods at a time when the means of conveyance were greatly restricted.

(*c*) The Provision of Siding Accommodation.[4]

It was arranged in July, 1915, that in accordance with instructions already issued to the railway companies by the War Office, branches of the Ministry of Munitions should refer to the War Office all orders for special trains, construction of sidings and other railway works, and questions affecting the control and working of the railways.

Upon the formation of the Inland Transport Branch within the Ministry in September, 1915, it was proposed that the new branch should communicate directly with the railway companies or the Railway Executive Committee in all matters connected with new sidings, the expeditious transit by rail of munitions, special railway facilities for workmen, and other similar matters within the scope of the Ministry's duties. The procedure agreed between the Departments concerned, in October, 1915, provided that the Inland Transport Branch should give the War Office full particulars as to new works and sidings or alterations costing more than £30 ; and that the War Office should then place the order through the Railway Executive Committee.

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[1] M.I.T./Gen./155.
[2] Hist. Rec./R./2020/1.
[3] General Procedure Minute, No. 18.
[4] M.I.T./Gen./1546.

No agreements were considered necessary for services on railway property during the government control of railways. Rent was to be charged when the property taken was not being used for actual railway work, that is, property which the Estates Department controlled. No standard form of agreement was decided upon, and no agreements were made for maintenance either of the sidings themselves or of works on the railway companies' own land. Nor were any arrangements made as to the rates to be charged for traffic delivered to sidings put in by the Ministry.

If a new factory or store was projected and sidings were required, or if additional facilities were necessary in connection with existing establishments under Ministry control, it was usual for the department of the Ministry concerned to consult the Inland Transport Branch in the initial stage, and the general lines of the work were agreed in consultation with the railway company concerned. A plan and an estimate were then submitted by the railway company, and when these had been approved the order was passed to the War Office, who instructed the railway company and advised the Railway Executive Committee.

Financial sanction for schemes was usually obtained by the Department concerned in the construction, but in certain cases sidings were constructed to enable the railway companies to deal adequately with munitions traffic or the conveyance of labour in certain areas, as distinct from those specially laid down to accommodate a particular establishment. In such cases the Inland Transport Branch obtained authority for the necessary expenditure.

Railway works constructed on government account were charged at cost price plus 12½ per cent. in accordance with an agreement between the War Office and the Railway Executive Committee, the railway company in each case certifying that the work had been so charged. This agreement was made as between two Government Departments, having regard to the fact that the railway companies were under state control and the actual cost of the work was not investigated by the Ministry. Further, such investigation seemed unnecessary, since any inflation of prices during the war was likely to be against the interests of the railway companies when they took over the new works after the period of state control.

No general policy was at first adopted in regard to the future transfer to the companies of railway works undertaken for munitions purposes ; but in May, 1918, a committee was appointed to consider the question, and it was agreed that all railway works constructed on government account during the period of the war, including those for the Ministry of Munitionss, hould be classified upon a uniform basis with a view to their ultimate disposal.

(*d*) THE DISCHARGE OF IRON ORE.[1]

One of the functions of the Inland Transport Branch was to conduct negotiations regarding the provision of mechanical grabs and other means of accelerating the discharge of vessels arriving at British ports

[1] M.I.T./Gen./1057.

with iron ore, and to expedite the distribution of the material to the furnaces in various parts of the country, thus supplementing the work undertaken by the Overseas Transport Branch.[1] Shortage of labour and unscientific methods of discharge were among the greatest of the difficulties experienced, and mechanical grabs were accordingly provided at a considerable number of ore-receiving ports. At several ports, also, schemes were adopted for the provision of cranes operating large size grabs. The objections originally raised by dock-side labourers to the introduction of such labour-saving devices were eventually overcome, and mechanical appliances were installed at some sixteen ports.[2]

The Ministry of Munitions made advances to the railway companies and others concerned towards the purchase of this equipment, having regard to the national interest involved. It was generally provided that the appliances should be taken over by the companies at the termination of the period of government control at their value at that date, or else the right was reserved to the Ministry to dispose of them as should be thought fit. The utility of the mechanical grab, compared with the former method of shovelling into tubs, is well illustrated by the results of a comparative test, during which the average lift by mechanical grab per hour was 37 tons 6 cwts., as against 17 tons 17 cwts. by tub, while the rate of discharge by grab in a shift of 9½ hours was 351 tons, as compared with 169 tons 11 cwt. by tub. This test was made with a small size grab of 17/14 cubic feet capacity, but the grabs generally adopted were of larger sizes giving a greater lift.

(*e*) Traffic Regulation.

The following instances serve as examples to show the steps taken by the Inland Transport Branch to improve the working of traffic, and to place it under proper regulation with a view to avoiding future difficulty. In October, 1915, the working of traffic in and out of Woolwich called for special attention, and a number of improvements in the arrangements for handling traffic throughout the Arsenal were adopted. The effect of these arrangements was soon felt, and the following figures illustrate the improvement in the working which resulted :—

Daily Average Number of Wagons (*October,* 1915—*April,* 1916).

	Arsenal.		Dockyard.		Traffic Outstanding.			Total.
	In	Out	In	Out	At S.E.&C. Junctions.	At other Stations	At Plumstead Stations	
Oct.—Nov.	335	309	110	106	361	760	294	1,415
Nov.—Dec.	312	309	99	110	335	391	294	1,020
Dec.—Jan.	319	306	98	97	222	341	264	827
Jan.—Feb.	343	350	115	117	112	118	224	454
Feb.—Mar.	367	338	94	94	129	110	221	460
Mar.—Apr.	384	376	99	97	134	83	186	403

[1] *See* above, p. 17.

[2] Ardrossan, Garston, Heysham, Maryport, Port Talbot, Tyne Dock, Barrow-in-Furness, Rothesay Dock, Irvine, Middlesbrough, Sunderland, Cardiff, Hartlepool, Manchester Dock, Newport (Mon.), Troon.

At the commencement of 1916, serious congestion also existed at Messrs. Vickers' works at Barrow, and special steps were taken to improve the position as the excessive quantity of traffic on hand was not only affecting the working but also the wagon supply. As a result of the attention given to this matter the average daily discharge was considerably increased, and the number of wagons on hand was reduced from 1,405 on 9 January, 1916, to 475 on 27 February following.

At a later date (August, 1917) it again became necessary to take measures for relieving traffic at the Royal Arsenal. Up to August, 1917, a considerable number of consignments, each of small weight, were received at Plumstead Station (S.E. and C.R.), for different stores and departments within the Arsenal. Consequently, the accommodation at Plumstead Station was severely taxed, while the method of dealing with these consignments involved an excessive amount of haulage from store to store in the Arsenal. In order to overcome these difficulties, it was agreed to construct a tranship shed at Plumstead where packages could be quickly sorted and loaded into separate railway wagons for each individual store in the Arsenal. The effect of this arrangement was that railway wagons were loaded to a greater capacity, resulting in a saving in rolling stock; that congestion of traffic disappeared; that the use of wagons and motor vehicles was reduced; and that less labour was employed by reason of the larger accommodation, crane power, and systematic lay out provided in the tranship shed. Whilst the total cost of the scheme amounted to £12,325, it was calculated that the economy in working expenses amounted to £16,881 per annum, the saving of 13 3-ton motor lorries represented £11,863, and the saving in labour £5,018 per annum.

III. Economies in Railway Equipment and Haulage.

The stringency of the position in regard to labour and rolling stock was met by continual efforts to economise in the use of wagons, and to reduce the amount of haulage.

(*a*) WAGON USAGE.

The inadequacy of wagon supply was one of the most serious problems before the Inland Transport Department. In the autumn of 1916 the approximate number of railway wagons in Great Britain was as follows:—

Railway-owned.	
"Open" vehicles	391,482
Other ,, ...	337,269
Total	728,751
Privately-owned.	
About	575,000
Grand Total	1,303,751

These figures did not include about 50,000 vehicles awaiting or undergoing repair.

Complaints of shortage came from factories and contractors in various parts of the country, and steps were taken to increase the number available for essential traffic. The railway companies were asked to contribute wagons out of their stocks for the iron-ore traffic, and the Ministry acquired trucks for the same purpose. Wagons were transferred from one company to another, empty coal trucks were loaded with iron ore on their return journey and certain Board of Trade regulations were relaxed.[1] It was then suggested that a general pool of railway wagons[2] should be adopted, as this would eliminate the time lost in sorting out wagons and returning them to their respective owners, and both mileage and engine power would be saved by the full use of all suitable wagons in any direction. A partial pooling arrangement was already in operation between three groups of railway companies,[3] but the pooling of privately-owned wagons presented greater difficulty, and a similar proposal had been abandoned by the Board of Trade in 1915, owing to parliamentary opposition.

In November, 1916, the Ministry of Munitions represented to the Railway Executive Committee the importance of establishing a pooling scheme, and by March, 1917, the wagons owned by railway companies had been pooled as far as possible. Privately-owned wagons were still unaffected, but by an Order under the Defence of the Realm Regulations (7*b*), issued in December, 1916, the railway companies were empowered to use empty private wagons for carrying traffic on the homeward journey. It was also decided in February, 1917, that when a trader failed to unload a railway-owned wagon within a prescribed time, the goods might be unloaded by the railway company and stored at the trader's risk and expense.

During the summer of 1917 no further advance was made, but in September of that year the question of a general pool was again raised, as a shortage of munitions traffic was anticipated, and benefit had already resulted from the partial common-user of railway-owned wagons and the back loading of private wagons. A conference was held on 1 November, 1917, between the Minister of Munitions, the President of the Board of Trade and the Railway Executive Committee; but it was finally decided, on 17 November, not to pool all wagons in Great Britain as, although desirable, the scheme was impracticable for various reasons. The private ownership system was universally recognised in this country, and there were then probably as many as 700,000 such wagons on British railways for a variety of purposes. These wagons were not generally suitable for the conveyance of merchandise, and any system of pooling would necessitate a central reorganisation to control distribution and allocation, for which the railway companies were not in a position to spare staff.

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[1] M.I.T./Gen./729, 953, 960, 1175, 1231; M.I.T./S./1642; M.I.T./B./1537.

[2] *See* also Vol. XII, Part V.

[3] (1) North-Eastern, Lancashire and Yorkshire, Midland, London and North-Western and Great Western; (2) Great Central, Great Eastern and Great Northern; (3) Caledonian, North British, and Glasgow and South-Western Railway Companies.

The question of railway transport in Scotland was particularly important owing to the iron ore traffic, and here again the chief problem was the shortage of wagons and locomotives. Efforts were made to extend the pooling system already in existence, and on 5 April, 1916, it was represented that full economy of wagons was not possible until this system included private wagons. The proposal was, however, strongly opposed by the Scottish Private Wagon Owners' Association, as the number of private wagons in Scotland was much smaller than in England and Wales, and a previous attempt of the railway companies to own all wagons had failed. A provisional scheme for pooling all Scottish wagons was eventually agreed upon, but the plan was abandoned in the autumn of 1917, by which time the majority of companies had come to the conclusion that it should not be put into force.[1]

(*b*) THE WORKING OF TANK WAGONS.

The transit of tank wagons over the railways prior to the outbreak of war was not considered to be of great importance. Consequently, the vehicles were run on slow goods trains and were frequently delayed at junctions. As a result of the war the demand for liquid products rapidly increased, while only a limited number of tank wagons was available. It was therefore arranged that Ministry-owned tank wagons, or wagons conveying Ministry traffic should run at scheduled times, and special facilities were given to urgent consignments. The transit of privately-owned tank wagons was also expedited, and it became possible to waive certain regulations governing the loading and despatch of inflammable liquids.

In consequence of the demand early in 1918 for the transfer of additional rail tank wagons for use overseas, an inter-departmental conference was held on 30 April, 1918, to discuss the general position. The existing system of control was investigated by a committee representing the Admiralty, the Petroleum Pool Board and the Ministry of Munitions, and, as a result, a representative executive committee was appointed under the chairmanship of Mr. F. Palmer, of Messrs. Rendel, Palmer & Tritton, to secure a closer system of co-ordination, and a better utilisation of the existing vehicles. The committee held its first meeting on 4 November, and it was agreed that returns should be obtained of the working of government-owned tank wagons, and that the Statistical Section of the Board of Trade should be assisted in the compilation of a list of privately-owned tank wagons, which had already been commenced. The cessation of hostilities, however, brought an end to the shortage of tank wagons, and the activities of the committee were suspended at the end of November.

(*c*) OUT-OF-GAUGE TRAFFIC.

Arrangements for the conveyance of unusual or what is termed "out-of-gauge" traffic formed an important part of the work of the Inland Transport Branch of the Ministry of Munitions. The extraordinary demands for conveyance of heavy guns, motor vehicles,

[1] M.R.T./Gen./703.

"tanks," tractors and other similar stores greatly taxed the limited supply of specially constructed vehicles. With a view to obtaining the use of every available vehicle constructed to convey such traffic in the country, the railway companies rendered considerable assistance by pooling the whole of their wagons of this class. Arrangements were also made for testing certain large articles at the place of construction instead of conveying them to another point for this purpose, and an estimated saving of 67,829 miles in haulage was thereby effected.

Further economy in the use of special trucks was ensured by despatching articles in a nearly completed state, entailing very little work at the base overseas, but enabling the traffic to be loaded in ordinary railway wagons.

(*d*) Standardised Loading.

The loading of traffic was standardised in order to secure safety and economy. The following figures show the estimated number of wagons required for the conveyance of cartridge cases before and after the loading was specialised.

Natures.	Estimated Total No. of Railway Wagon Loads.		Estimated Saving in Wagon Loads per month.	Estimated Saving in Shunting Cost per month.	Estimated Saving in Covered Storage Space.
	Old Method per month.	New Method per month.			
				£	per cent.
Brass Cartridge Cases 18-pdr.	7,432	1,206	6,224	1,250	60
Brass Cartridge Cases 4·5-in.	8,624	1,232	7,392	1,480	60

The change in method also obviated the need for providing returnable boxes for the conveyance of brass cartridge cases, which were thenceforward carried loose in the trucks. The new method was introduced as a result of an inspection of traffic arrangements at Central Stores Department depots. An examination of records revealed the fact that the vehicles were being loaded considerably below their carrying capacity. When the cartridge cases were packed loose in box railway wagons the carrying capacity could be maintained, and this eliminated the return of contractors' and Ministry transit boxes, which involved the user of rolling stock on the return journey equal to the number utilised on the outward journey. Experience also showed that the tendency was for transit damages to decrease under the new system, since the weight and bulk of the packages when packed in transit boxes and handled by female labour had caused boxes to be dropped and the contents damaged.

Similar satisfactory arrangements were made in connection with the loading of other sizes of cartridge cases, shell and other traffic, and the standardisation of the loading of traffic resulted in great economy in railway wagons, with consequent economy in railway shunting, and also in a saving of packing cases, storage space, and labour.

(*e*) ALLOCATION OF MATERIALS.

A very considerable proportion of the munitions traffic to be handled consisted of raw or semi-manufactured materials, which had to be conveyed from port to store and thence to factory. The sites of the stores were themselves chosen with a view to reducing the amount of haulage required.[1] The departments concerned co-operated with the transport authority in a systematic allocation of materials, based on the geographical position of their stores or factories in relation to the various ports whence materials were to be conveyed. For this purpose allocation charts were prepared, distinguishing the advantageous and disadvantageous routes from the various ports and forging depots to the various manufacturing centres. These charts also showed the mileage of the various routes and the nature of the shells manufactured in each town. They thus provided a rapid means of judging the source of materials for any individual factory or store which would best economise haulage.

IV. Munitions Transport by Road and Water.

The stringency of the railway position gave rise to a general policy of diverting short-distance traffic to roads and waterways.

(*a*) MOTOR TRANSPORT.

When the Ministry of Munitions was first established the War Office arranged to supply motors for the use of travelling engineers and motor lorries required in connection with the construction of national factories, and in December, 1915, a special Army Service Corps Mechanical Transport Company of 80 vehicles was placed at the disposal of the Ministry. The supervision of these vehicles was at first with the Establishment Branch, but in April, 1916, it was transferred to the Inland Transport Branch. At that time the vehicles numbered 150 lorries and 28 motor cars, but by the end of 1918 there were 2,054 vehicles in use, of which 390 were hired and the remainder under the Army Service Corps.[2]

In April, 1916, it became necessary to form an additional Army Service Corps Company at Manchester, and in order to meet increasing demands the Ministry was obliged to purchase vehicles which were handed over to the War Office for maintenance purposes. Arrangements were also made to meet the shortage of steam wagon drivers whereby the Ministry sold steam wagons to contractors on the hire purchase system, subject to a right to hire them for a period of seven years, the contractors being responsible for running and maintenance.[3] The

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[1] *See* below, Chap. III.

[2] These included 589 petrol lorries, 162 light vans, 258 steam lorries, 120 trailers, 594 light cars and 331 cycles or cycles with side-cars.

[3] The vehicles purchased by the Ministry consisted of 68 3-ton petrol lorries, 56 steam lorries, 42 trailers, 53 light cars, 12 light vans, 10 char-à-banc bodies fitted to A.S.C. chassis, 8 ambulances, 2 auto-carriers, 38 vehicles transferred from national factories. With the exception of the steam wagons and trailers these were maintained by the War Office. (M.I.T./D./674.)

lorries controlled by the Inland Transport Branch operated in practically all parts of Great Britain. A considerable fleet was maintained in Glasgow and a few vehicles in Ireland. The following are details of the work performed during the 12 months ending October, 1918 :—

Miles run empty	1,958,525
,, ,, loaded	2,533,001
Total miles run	4,491,526
Tons carried	1,903,259
Number of loaded journeys	559,008

Originally, lorries were allocated to government establishments as occasion required, but it was found more economical to form central offices to which transport requirements could be sent, as empty return journeys could then be avoided, and the proportion of loaded mileage run was increased from 45–63 per cent. Lorries, light cars and motor cycles were supplied to controlled and uncontrolled firms as well as to government establishments, provided that work of national importance was being done. Charges were made on a flat rate per day, with an additional payment for mileage in excess of 40 miles. The scale of charges to private firms was higher than to government establishments, and constant revision of the two scales was necessary to keep pace with market rates.[1] For the period of six months ending October, 1918, the total charges raised by the Motor Transport Section amounted to £293,142. Of this amount, £247,358 was a government liability, but the balance of £45,784 was recoverable from private firms.

This system of centralising transport resulted not only in greater economy but also in better arrangements for dealing with cases of emergency. During periods of congestion, the railways were relieved by road transport in the principal munitions areas ; and the effects of the freezing of canals in February, 1917, and of the railway strike in September, 1918, were mitigated by the prompt use of lorries.[2]

The necessity for hiring lorries first arose at the end of 1916, but owing to the high rates prevailing in the North, vehicles were hired by the Ministry, with a few exceptions, only South of a line drawn between London and Bristol, and used mainly in the North of England and in Glasgow. By the co-ordination of factory requirements, hire was possible at minimum time rates for fixed periods, and it was estimated that this system of periodical contracts resulted in a saving of £39,147 from January to November, 1918.

A regular parcel collection and delivery service by light vans was put into operation in August, 1918, to serve 33 departments.[3] The savings thus effected amounted to 1,800 miles or £58 15s. per week. Cars were also supplied to other Departments, such as the Ministries of Food, Shipping, Labour, the Board of Education, the Board of Trade, the Office of Works. From the end of 1916 use was made of the services of the Royal Automobile Club, originally offered to the War Office at the outbreak of war. The owners undertook to provide a car with driver for 6s. a day, the Government providing petrol and defraying the actual

[1] M.I.T./Gen./651, 1225. [2] M.I.T./Gen./1018 ; M.I.T./C./1829.
[3] M.I.T./F./1267.

cost of up-keep. The extent to which this service was used is indicated by the fact that £20,165 was paid to the Club for the year ending November, 1918, and the saving compared with the normal rates of hire was about £60,495.

The attention of the Inland Transport Branch was drawn to the waste of transport capacity where motor vehicles were running empty or lightly loaded; and on 22 April, 1917, an arrangement was made at Birmingham whereby owners having vehicles travelling empty any portion of their day's journey and traders requiring transport should notify a central office. Loads were then obtained for the otherwise empty journey, and a scale of charges was fixed based upon the rates for loaded journeys. All cash transactions passed through the central office, and the Ministry retained a commission of 4 per cent. In November, 1917, in view of the satisfactory results obtained, another office was established at Leeds, with branches at Sheffield and Bradford, and similar schemes were started at Liverpool and Manchester, under the Local Chambers of Commerce. Further developments were, however, abandoned upon the formation of the Road Transport Board in January, 1918.[1]

(*b*) CANAL TRANSPORT.[2]

Late in 1916 the Inland Transport Branch conducted an enquiry covering all the principal waterways in the country, in order to ascertain whether the canals could be utilised to a greater extent and thus afford relief to the railways. It was, however, found that so far from being capable of accepting more tonnage, canal traffic was greatly declining on account of shortage of labour. Towards the end of 1916 the labour position was becoming so serious that several important carriers and waterways anticipated that they might have to cease operations. The Inland Transport Branch called a meeting on 20 December, 1916, of the principal canal owners and carriers, formed a committee and submitted a report on the whole subject, and ultimately the Canal Control Committee reported that the canals were already being used to their maximum capacity having regard to the depleted staffs available.

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[1] M.I.T./B./2136. [2] M.I.T./Gen./428.

CHAPTER III.

STORAGE.[1]

I. The Organisation for Storage.[2]

(*a*) The Position in 1915.

During the early months of the war the demand for munitions was so far in excess of the supplies available that the question of storage on any large scale did not arise. In the summer of 1915, however, with the development of imports and the increased production both at the Ordnance Factories, Woolwich, and by trade firms, the matter of stores organisation became a problem of some urgency, and when the Ministry of Munitions was formed in June the situation was serious. The principal difficulty of the moment lay in the dangerous congestion in the Ordnance Stores at Woolwich where a very large proportion of deliveries and inspection had always been centralised. Practically all contracts were placed for delivery at Woolwich where the work of inspection was centralised, except for a comparatively small proportion of munitions for which inspection had been arranged at works since the outbreak of war.[3] The only other stores in existence were at Enfield and Weedon for rifles and parts, and at Teddington for gauges, taps, dies, etc.[4] The position in regard to storing gun ammunition components was rendered particularly grave by the expansion of shell manufacture under the Ministry. Not only did the increased programme entail a general increase in the storage capacity required for materials, parts and completed munitions, but the introduction of piecemeal manufacture involved the storage of the separate parts until the whole could be finished, and the importation of incomplete ammunition from America necessitated storage pending completion. In view of these three developments it was essential that before the new orders placed in the summer of 1915 materialised a radical change of system should be evolved. Fresh organisation was required to deal with the provision of actual storage accommodation, to effect the movement of materials and components in or out of stores as required and to secure the maintenance of accurate records and accounts.[5] The difficulties to be encountered in any attempt to set up such an organisation seemed to be almost insuperable at a time of such great stress.

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[1] Hist. Rec./H./2000/1 ; Hist. Rec./R./1125/1, 7 ; 1122/10; (Printed) *Weekly Report, passim.*

[2] Hist. Rec./H./1340/1.

[3] *See* Vol. IX, Part II.

[4] Hist. Rec./R./1125/3.

[5] Vol. III, Part I, Chap. II.

(*b*) Development of the Ministry's Organisation for Storage, 1915–1916.

As a preliminary to the organisation of a storage department in the Ministry, a conference was held on 30 August, 1915, with the Deputy Director of Ordnance Stores, to discuss the position of the Army Ordnance Stores (Woolwich) in relation to the new system. It was decided that the new department should become responsible for storing output from all contracts. As regards the disposal of components and materials stored it was laid down that the Ordnance Stores should feed the Ordnance Factories and certain riverside firms, while the newly established storage section of the Ministry should meet the demands of the trade contractors and, when ready, the National Filling Factories. As most of the goods requiring storage were connected with the filling of shell, the new storage section (Munitions Stores Department) was organised under the control of the department which was connected with gun ammunition filling and was formally established on 4 September, 1915.

The department was organised in two sections dealing respectively with circulation and actual storage. The whole system of circulation was based on the proper use of the three forms, "issue warrants," "inspection notes" and "advice notes," of which at least six copies had to be completed by contractors for each delivery. This procedure was accepted by a conference of the principal firms, but considerable difficulty was experienced in putting it into practice. Although this section dealt with questions affecting the movement of goods, a committee of supply officers was responsible for economical circulation.

On the formation of the Munitions Stores Department in September, 1915, the immediate necessity was the relief of the congestion at Woolwich. The first action of the new department in view of this urgency was the acquisition of a large store at Birmingham for shell, cartridge-cases, components and metal. The buildings of the Midland Railway carriage works were taken over under the Defence of the Realm Act, on 10 September, and became the first of the large number of similar stores eventually controlled by the Ministry throughout the country. In addition to storage and inland circulation the department was responsible for the clearing and forwarding from ports of the deliveries from overseas contractors, and in connection with this duty undertook the fusing at Horley and Devonport of 18-pdr. shell from America. By the end of the year 14 stores were in working order under the department and several others under consideration.

At the beginning of 1916 fresh responsibilities devolved on the Munitions Stores Department by the revision of the arrangements in force with regard to the supply of components. Up to this time components had been delivered to Woolwich, re-issued to the Ministry and finally returned to Woolwich in complete rounds. This procedure, involving unnecessary transit and other complications, was discussed at a conference between the War Office and Ministry of Munitions on 14 December, 1915, with the result that the Ministry undertook the whole responsibility for components from their

manufacture to the delivery of complete rounds; buildings and staff at Woolwich being accordingly transferred as from 24 January, 1916. In the following month a further alteration was made with a view to facilitating the assembling of ammunition. As arranged in June, 1915, the Ministry was responsible for this work and was bound to deliver to the Army Ordnance Department only filled and assembled rounds. Such an agreement, though satisfactory in principle, soon became impracticable. Owing to the exigencies of manufacture, components could not always be produced in marriageable proportions, and in February, 1916, the Army Ordnance Department began to take charge of the separate components in addition to complete rounds and to arrange for their marriage. On 1 March a provisional arrangement was made for marriage to take place in France, and as this proved to be the most practicable procedure it was eventually made permanent.[1]

(*c*) Expansion in the Work of Storage, 1916.

Some idea of the tremendous increase in the quantities of munitions handled in the stores controlled by the Munitions Stores Department during the first half of 1916 may be gathered from the number of documents which were dealt with each day. The numbers of inspection and advice notes and issue warrants in January, 1916, were 150, 200 and 50 respectively each day. In July, 1916, the corresponding figures were 1,000, 1,049 and 173. The average amount of stores handled per day in January, 1916, was some 1,358 tons at a cost of approximately 4s. 1d. per ton, while in July it was 4,812 tons and the cost only 2s. per ton.[2] This increase was accompanied by many difficulties, including that of finding adequate accommodation and skilled staff, of correctly identifying imported munitions and material at the port of entry, and of temporary stoppages in the flow of materials through stores, such as the check in assembling H.E. ammunition due to the change in the gaine during the winter 1915–1916. During the first week of January, 1916, 14,000 tons of ammunition and 1,000 tons of raw material arrived at the various ports, and the problem of dealing with such large quantities was always complicated by the irregularity of the ships' arrivals. By March, 1916, 2,500,000 sq. ft. (57½ acres) of covered floor-space had been provided, of which about 900,000 sq. ft. was afforded by specially constructed sheds. This accommodation was used not only for warehousing stores, but also to a considerable degree for inspection and for final processes such as the painting of shell. Later in the year the Ministry undertook the storage of material for Russia in addition to its own requirements, and proposed to acquire an additional 1,000,000 sq. ft. for this purpose at St. Helens, Walton, Liverpool, Manchester and Birkenhead. At the same time difficulty arose as to the storage capacity for filled ammunition which the Ministry had agreed to provide for the War Office. The accommodation which under this agreement should hold four weeks' output from the filling factories proved

[1] C.M.4/728; cf. Vol. VIII, Part II, p. 6
[2] Hist. Rec./R./1350/2.

to be inadequate, partly owing to the change in programme resulting in reallocation among the filling factories and partly to restrictions in the amount of propellant to be stored in any one magazine. Fresh accommodation was accordingly arranged[1] at Creedon Hill, Bramley and Altringham.

A still more remarkable development of this year (1916) was the establishment of inspection bonds all over the country for the receipt, testing and storage of contractors' output of all kinds, except explosives, which throughout the war remained in the custody of a special storage section of the Explosives Supply Department. The growth of these bonds was a noteworthy feature of the Ministry's organisation for inspection and has been treated elsewhere.[2] The control of the local inspection bonds rested with a branch of the Gun Ammunition Department (A.M.2) under Major the Hon. L. H. Cripps, which had originally been established in the summer of 1915, to receive uninspected shell and components from overseas.[3]

(*d*) ORGANISATION OF THE CENTRAL STORES BRANCH, 1917–18.

The Ministry's administration of storage was thus decentralised, and as the storage sections of the various supply departments increased in activity, the difficulties involved in decentralised control were becoming apparent. In particular, it was obvious that under the existing system the control over issues of material was inadequate, and mainly with a view to improving this control, plans were brought forward at the end of 1916 for the centralisation of the various storage authorities of the Ministry in a Central Stores Branch.[4] In April, 1917, this scheme received sanction, and the Central Stores Branch took over the control of all the inspection bonds and stores except those under the Explosives and Trench Warfare Supply Departments, thus unifying the administration of about 120 stores and inspection bonds. At this date the property of the branch included more than 4,500,000 sq. ft. of covered floor space and over 70 acres of open stacking ground, the approximate value of the stocks in hand was £100,000,000, while the average tonnage in and out of store had reached 100,000 tons weekly.[5] The branch was organised in four main groups responsible for (*a*) stores accounting, (*b*) stock-taking and audit, (*c*) stores administration and (*d*) works. The first section was in many respects the pivotal part of the Ministry's cash department, as it assumed control of the issue warrants which formed the basis of all record and circulation, but its organisation falls more properly under the story of finance.[6]

The actual administration of the stores was organised by geographical areas. The various depots directly controlled from headquarters were grouped under district superintendents in charge of one or more such areas. Thus, by January, 1918, there were 14 areas, Birmingham I and II, Liverpool I and II, Midlands, Ireland, Leeds, London I, II and III, Manchester, Northern I and II, and

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[1] HIST. REC./R./1350/3.
[2] Vol. IX, Part II, Chap. VI.
[3] Hist. Rec./H/1300/1, p. 12.
[4] M.C. 761 ; A.C. 54.
[5] HIST. REC./R./1125/2.
[6] Vol. III, Part I.

Western, each containing from five to 25 depots, the average number being about 12 in each area. In addition to these, 28 stores which were administered by contractors came within the jurisdiction of the branch.[1] In 1917, when the Central Stores Branch started work, the system of contracting for storing Ministry property was far from satisfactory, and it was decided that the branch should have local representatives to bring contractors' stores under its control,[2] and that it should be consulted before any contracts were placed which would involve storage. The whole question of contract storage was again under discussion as late as August, 1918, when it was laid down that tender forms should show the provision made for proper stacking and stock-taking and that contractors should accept all fire risks.[3] The goods which contractors stored in their own premises included metals of various kinds, medical and other glassware and porcelain, X-ray tubes, machine-tools, aeroplane timber and cases for bombs.

In addition to ammunition and components, by 1918 the Central Stores Branch had undertaken the storage of trench warfare munitions and materials, mechanical warfare (tank) accessories, guns, machinery, tools, aeroplane parts, engines, tyres, boxes, and stationery, as well as very large quantities of raw materials, textiles and scrap. The trench warfare stores had not been included in the original organisation of the branch in April, 1917, but at that date had just been centralised in one section with the Trench Warfare Filling Factories. They remained under this separate control until the following spring, when on the disintegration of the Trench Warfare Supply Department the inland stores for parts and materials were handed over to the Central Stores Branch, and those which, owing to the former department's exceptional responsibility for the issue of its munitions, had served as forwarding depots were transferred to the Army Ordnance Department, thus bringing storage and issue into line with that of other munitions.[4] The Mechanical Warfare Department also reserved control over such of its depots as served for experimental work, particularly in connection with tank construction,[5] but by 1918 the Central Stores Branch had a number of stores for tank components, engines, etc.

II. Sites and Buildings.

Apart from questions of finance the main problems of stores administration to be considered were the choice of sites and the conversion or erection of buildings. In choosing the sites for new stores, one of the main considerations was the reduction of haulage to the minimum possible between source of materials, the manufacturing shop and the port of despatch. Stores were generally placed either in the neighbourhood of manufacture or on the route between that and the next destination of the goods, whether filling factory, contractors' works or Army Ordnance Stores, or in as close proximity as possible to supplies of ammunition boxes. It was a definite policy to take over existing premises rather than to build new ones. Hence, the choice of site was

[1] Hist. Rec./R./263.39/1.
[2] C.S.B./Gen./11.
[3] C.S.B./Gen./13.
[4] M.C. 646.
[5] M.C. 179.

further restricted by the availability of buildings suited for storage purposes. Local officers investigated the suitability of premises, and a properties register was also kept. Many buildings otherwise suitable did not contain floors capable of bearing the heavy weight of shell or metals, or had no adequate facilities for dealing with a large volume of traffic. For some stores which were intended for explosive material it was desirable to find an isolated position away from centres of population, and this greatly increased the problem of securing suitable buildings. Nevertheless, a very large number of places were acquired by the branch, and, by September, 1918, the stores under its control included various engineering or manufacturing works, brickworks, which were frequently in the open country and unwanted during the general cessation of building activities, breweries, available owing to the decrease in the use of grain for liquor, garages and mews, railway property or tramway sheds, glassworks, cattle markets, schools, tennis courts, skating rinks, municipal halls and race-courses. When buildings were not available the local inspectors selected suitable sites requiring as little preliminary earthwork as possible, and preferably with a ground level above that of the railway. No steel could be spared for constructional purposes, and the material usually employed was timber. Owing to the heavy loads, frequently reaching to 1,700 lbs. per sq. ft., only single-storey buildings were usually built, with railway sidings on each side. The earlier form of shed was built about 60 ft. wide with the roof on columns 15 ft. apart. Experience showed that this plan impeded trucking, and the standard design ultimately adopted had spans of 60 ft., the total width being 120 ft.; 13 ft. 6 in. was the standard height, and the maximum length 1,000 ft., about the same length as a train of 50 wagons; but probably 900 ft. was the best length for economical working. Floors were usually of concrete, raised to the level of the floor of the trucks or wagons on the rails, and where the whole building covered a greater area than 50,000 sq. ft. this space was shut off by fire-proof walls. In addition to actual store buildings, accommodation was provided at the large stores for mess-rooms and canteens, while in October, 1917, specially constructed air-raid shelters were added.

III. Methods of Storing Gun Ammunition and Components.

Of the stores under the administration of the Central Stores Department the three most important classes were those for empty shell, for components and for filled shell. The first of these three was not so urgently required in 1916, and once the filling factories were really under way they were able to keep pace with manufacture. As manufacturers' output increased, however, large stocks accumulated at Plymouth, Swindon, Horley, Neasden and Aintree, while in March, 1917, the change in the ammunition programme resulted in a large surplus of empty shell.[1] In September the Munitions Council raised the question of the condition of the large stocks on hand and an investigation was made. The Central Stores Department in its report divided the shell into four classes, according to its condition, and it was found

[1] D.D.G.(C)/C.M.G./291/1.

that in all the stores the percentage of all natures of shell in the different classes were as follows :—(*a*) uninspected 12·5 per cent. ; (*b*) ready for issue 60·8 per cent. ; (*c*) requiring rectification 23·8 per cent., and (*d*) finally rejected 2·9 per cent. These percentages varied very considerably in the different natures, those for 9·2-in. for instance being (*a*) 16·2 per cent. ; (*b*) 65 per cent. ; (*c*) 18·8 per cent., and none rejected ; while the 6-in. had (*a*) 25·6 per cent. ; (*b*) 37·3 per cent. ; (*c*) 33·7 per cent., and (*d*) 3·4 per cent. The work of rectification was carried on largely at the stores themselves, and consisted chiefly of cleaning and repainting.[1]

Empty components were stored in buildings at the chief centres of production, the same premises being frequently used for empty shell and components. As there was practically no danger beyond ordinary fire risks to be feared from these stores, use was made of buildings situated in large towns which were available for the Ministry but were unsuitable for storing filled ammunition. Filled components were bonded until proof and then despatched by the Ministry to the Army Ordnance Department or to the assembling factories, according to the nature of the shell.

The storage of filled shell was a question of vital importance, as lack of precaution in this matter was certain to result, at the best, in deterioration of the shell, and at the worst, in the complete destruction of the store and any surrounding buildings. In 1915 it was decided that the Ministry should provide at each National Filling Factory storage capacity for 4 weeks' output which was to be under the control of the Army Ordnance Department. Accumulation at the filling factories themselves was thus prevented, but the accommodation soon proved inadequate and fresh stores had to be added. By September, 1916, it had become necessary to hold six weeks' supply of filled ammunition in England, so that existing capacity had to be extended by 50 per cent. Shell stores were provided at Hereford, Quedgeley, Lewes and Middlewich, and capacity for the equivalent number of cartridges in other districts. During the last few weeks of the year stoppage of overseas traffic and other set-backs due to bad weather caused congestion at the filling factories' stores, and at the Banbury Filling Factory concrete platforms were laid down by the sidings and covered with a dutch barn roof to take the surplus which could not be held in the ordinary stores. As this method proved satisfactory it was later followed in extending the capacity at several of the other stores.

The safety conditions necessary in such stores naturally added very considerably to the problem of securing adequate accommodation. After an explosion at the ammunition dump at Rouen in the spring of 1916, a Committee on the Storage of Filled Gun Ammunition was appointed to consider the whole question. Some of the requirements laid down by this committee, however, proved to be impracticable in actual working, and it was found necessary to abandon the regulations drawn up for the ideal storage programme and make the best of existing conditions. Thus the recommendation that shell stores should be under 4,000 sq. ft. in area and at least 200 yards apart, was never

[1] M.C. 178.

carried out, as it would have entailed the acquisition of some 2,000 acres of additional ground, while the cost of administering a large number of small scattered depots would have been very heavy.[1] The larger stores were made as safe as possible by means of sand-bag traverses, earth mounds or partitions of concrete or double galvanised iron. It was arranged that propellants should be stored in different buildings from H.E. shell, that fixed ammunition or boxes containing complete rounds should not be stored with either propellants or H.E. shell of other natures, and that chemical shell, bombs and grenades should be kept separate from other ammunition.[2] Within the same store, where possible, amatol-filled shell were stacked between lyddite or trotyl-filled shell, as the former were less easily detonated and might thus serve to localise any explosion occurring among the others. In the autumn of 1916, when the committee issued its report there were some 8,750,000 rounds of shell and cartridges to be stored. A year later it was estimated that by the spring of 1918 the total stocks of filled ammunition would amount to :—

18-pdr.	21,000,000
4·5-in.	6,844,000
60-pdr.	2,304,000
6-in. how.	5,144,000
8-in. how.	1,304,000
Other natures	1,448,600
Total	38,044,600

of which about one half would have to be stored in England. Thus by October, 1918, the total space available or in preparation for filled shell had reached 3,788,427 sq. ft., of which some 1,422,858 sq. ft. was occupied, and half of the remaining 2,000,000 was under construction.[3]

IV. Magazines for Explosives.[4]

The custody of explosives presents very special difficulties. Before the war it had been undertaken by the Chief Inspector of Ordnance Factories, who had stored the reserves remaining from the South African War and was responsible for all filling. Before the formation of the Ministry of Munitions the War Office had found it necessary, as filling was about to be undertaken by the trade, to make distinct arrangements for the store-keeping of high explosives, and for their issue to filling contractors and to the Ordnance Factories. This function was among the duties of A.6., the branch of the Directorate of Artillery, established in conjunction with the Committee on High Explosives. Little difficulty was experienced in regard to storing propellants until June, 1915, when the Ministry became responsible for providing and storing these as well as high explosives. Both classes of explosive were then about to exceed the immediate capacity for consuming them, and in particular there was urgent need to provide

[1] D.D.G.(C.) C.M.G./291/1.
[2] *Ibid.*, 291/2.
[3] *Ibid.*, 291/1.
[4] HIST. REC./H./1540/1.

storage for imported propellants. The only magazines available were at Woolwich, Purfleet and Weedon, and were just able to accommodate the output of British manufacturers, but were utterly inadequate for dealing with the large deliveries expected from overseas. Mines at Dudley and Northwich, and caves at Reigate were utilised at once, and magazines in a few obsolete forts were taken over from the War Office, but the capacity thus obtained was very small, and a special section of the Explosives Supply Department was formed to be responsible for storage. It was estimated that at least 20,000 tons of propellants would have to be provided for above the requirements of filling factories, as well as any surplus of high explosives over the three weeks' supply stored at the factories, so that the question of storage might well be described as urgent.[1] By November, therefore, the Explosives Stores Section of the Explosives Supply Branch was building new magazines and undertaking the ordinary storage duties in connection with explosives, as well as the task of supplying filling factories and notifying them as to correct charges, and of meeting the demands of the Allies.

It was even more difficult to find existing premises suitable for magazines than for storing other classes of warlike material, as isolation from other buildings, suitability from a military point of view and a location outside the area of air-raid attack and convenient to filling factories were particularly desirable, in addition to the qualifications needed for all stores. Certain brickworks were found capable of adaptation and also possessed the advantage of being able to afford a nucleus of labour formerly employed in the works ; disused tunnels were adapted, and hulks on the Thames and the Sloyne (Liverpool) were also used. The capacity of individual stores varied from 600–2,500 tons of propellants and from 225–750 tons of H.E. for surface storage, or up to 2,000 tons underground. By the end of August, 1916, 20 magazines for propellants and 13 for H.E. were in use or under construction, giving a capacity of some 41,250 tons, while the value of stocks held amounted to £6,500,000. During the spring of 1917, questions were raised as to the safety of the storage at Liverpool docks, and in April a committee was appointed to investigate the matter. While it was recognised that ports were more difficult to render safe than inland stores, and that considerable damage to the docks and shipping was inevitable in the event of any explosions taking place, it was impossible to avoid storage at Liverpool as all the imports from Canada and America were brought to that port. The quantity stored actually at the dock was kept as small as possible ; a Danger Building Officer was appointed in April, 1917, while in June, 1918, an executive committee was also formed to control the handling of all explosives at Liverpool.[2]

Operations at all magazines were conducted as far as possible on identical and systematic lines, all instructions as to procedure being issued from the director and co-ordinated by means of "storage circulars." Thus any point arising in one magazine which might apply to others was referred to headquarters, and a record of the ruling made issued to all other magazines. In this way considerable correspondence

[1] C.R./C.M.4 R./188. [2] C.R.V./Gen./0297, 0544.

was avoided and methods were standardised[1] in the 78 magazines and 20 other stores which were eventually controlled by the Explosives Supply Department.

V. Miscellaneous Stores.

Apart from gun ammunition, components and materials, a large number of stores was required for boxes, aeronautical and trench warfare supplies. Large stocks of boxes were held in every centre of production, but their storage presented little difficulty beyond that of adequate space, and in some places boxes were stacked in the open. The Aeronautical Storage Section was included in the Central Stores Branch in August, 1917, and administered the stores at the Royal Aircraft Factory, Farnborough, and at Sheffield, Birmingham and Regent's Park. Aircraft supplies involved very considerable storage owing to the great difficulty experienced in obtaining concurrent deliveries of the various parts and many complicated instruments required in the finished machine. In particular, the engine took nearly twice as long to produce as the body. At the beginning of 1918 a number of French aero-engines were imported, but most of them had to be stored to await missing parts or even a general overhaul. In the spring lack of balance in the manufacture of parts made it necessary to store a large number of aeroplanes awaiting engines, and by August, Handley Page machines were coming forward in advance of their engines and had to be stored at the American Assembly Factory, Oldbury. A.G.S. parts, *i.e.*, the small machined parts of aeroplanes, were used in such quantities that it was found advisable to buy in bulk and store for re-issue to the trade, and in 1918 a central depot was also instituted in Birmingham to receive and re-issue stampings and pressings.[2] Thus by September, 1918, some 25 stores were devoted exclusively to aeronautical engines, parts and material. Trench warfare materials and munitions were received at 16 stores, but few of these were kept exclusively for the purpose, the trench warfare supplies being frequently accommodated in the same store as empty shell and components after the centralization of control over the Trench Warfare Supply Department's stores. The principal difficulty with this type of munitions was the experimental character of their manufacture, involving frequent change in design and the consequent production of obsolete types, while it was impossible accurately to foretell the requirements. In some cases this difficulty was overcome by agreement with the manufacturing firms who undertook to store their output until it was required; in others by a certain amount of mechanical rectification undertaken at store.[3] Guns and carriages were stored at Woolwich, and parts, engines and accessories for tanks chiefly in the Midlands or at Glasgow, while three artillery stores were placed at Coventry, Erith and Southampton. Thus the stores under the Central Stores Branch covered practically every type of munitions required, with one important exception. No small arms or small arms ammunition were stored by the branch, but the reserves of these were held in store for the Army at Weedon.

[1] For a more detailed account of this work *see* Hist. Rec./H./1540/1.
[2] Vol. XII, Part I. [3] Vol. XII, Part II., Chap. III.

VI. Labour and Efficiency.

A system of comparative costing was introduced into the inspection bonds at their inception, and was applied to the general stores in September, 1917. Towards the end of that year, standard costs were set up and a section was established for experimental purposes.[1] Any general provision of elaborate mechanical contrivances was impracticable, but so far as possible, inventions, adaptations or the results of experience were made known to all stores officers through the *Ministry of Munitions Journal*, the methods of handling evolved in one place being published for the guidance of all. Thus, in the Journal for August, 1917, articles appeared dealing with the layout of shell stores to secure continuous circulation and with the advantages and disadvantages of various forms of stacking.[2] Approximately two-thirds of the employees in the stores were women, and although difficulty was experienced throughout the winter, 1916–17, in obtaining sufficient building labour for the construction of stores, once the stores were at work there was rarely any real scarcity of suitable labour in 1917. In many cases the former staff of works taken over by the Ministry were retained, and in 1916 about a third of the labourers at magazines were formed by military fatigue parties.[3] In 1918 trouble arose on the question of wages, and more difficulty was experienced in securing adequate numbers. By September, 1918, the number of workers at all the depots had reached 5,430 men and 10,916 women.[4]

VII. Storage Capacity 1918-19.

Some idea of the extent of the depots controlled by the Central Stores Branch in 1918 may be gathered from the approximate value of the stocks in hand during March, which amounted to nearly £100,000,000 and was distributed among the different stores as follows :—

	£ millions
Shell and components	78·16
Boxes, packages and timber	4·78
Raw materials	9·87
Aeronautical materials	3·45
Artillery	·50
Mechanical warfare	1·55
Miscellaneous (including materials other than Ministry property)	1·65

A large proportion of these articles was constantly circulating to and from the stores. Thus in one fortnight of the month 5,776 wagons, lorries and barges were unloaded and nearly 4,000 were loaded at the depots. A considerable amount of rectification was also carried on, the total for March being 17,043 18-pdr., 17,760 4·5-in., 12,105 6-in., 14,166 9·2-in., and 68,582 other natures of shell. The tonnage

[1] Hist. Rec./R./1125/6.
[2] *Ministry of Munitions Journal*, No. 9 (August, 1917).
[3] Hist. Rec./H./1540/1.
[4] M.C. 761.

handled by the Central Stores Department was perpetually increasing and by the autumn of 1918 the weekly allocations to store, exclusive of shell from home manufacturers, were approximately :—

	Tons.
Shell (overseas)	14,464
Forgings (home and overseas)	1,973
Steel billets (home and overseas)	52
Steel rod (home and overseas)	195½
Steel sheet (home and overseas)	392
Steel wire (home and overseas)	60
Raw materials (overseas)	5,258
	22,394½

This tonnage was distributed over 168 stores, of which 21 were situated in Birmingham alone, 10 in Glasgow and 16 in London, and of which the total area amounted to some 15½ million sq. ft.

The arrangements made by the Central Stores Branch were necessarily based very largely on the gun and ammunition programmes, but, in 1917, the increasing demands of the aeronautical works gave rise to a fresh class of extensions. Thus in August 1917, new stores of some 200,000 sq. ft. in area were required for the timber which was to be imported for aircraft works,[1] while as has already been shown, in 1918 aeronautical storage absorbed a large proportion of the whole stores capacity. Arrangements made by the branch to provide accommodation were at times entirely changed by circumstances beyond its control. In this way the stores erected at Plymouth early in 1916 became useless to the branch in 1917 owing to the Admiralty decision not to use Plymouth as a port for importing munitions, and were handed over to the Ministry of Shipping for storing grain.[2] A reduction in the gun ammunition programme, so far from lessening the storage requirements added to the difficulties of the branch, as the impossibility of reducing the rate of manufacture, especially in America and Canada, as quickly as that of filling necessitated a sudden extension of storage for empty shell and components. In the spring of 1917 the accommodation which was required in this way amounted to 500,000 sq. ft.[3]

Unlike the various supply sections the Central Stores Department found its work very greatly increased by the cessation of hostilities. The desire to effect a speedy turnover to peace industries, combined with the return of munitions from overseas, laid additional burdens on the existing capacity. Many factories could not resume their normal work until their production and in some instances their machinery was removed, while in others it was impossible to cease munitions manufacture immediately, and additional output had to be accepted and stored. At the same time, masses of material were flowing back into the country from France. Much of this was of high value and could be liquidated to far better advantage by gradual sale than by immediate forced auction. While the demand for storage was thus increased the available capacity was reduced, owing to the necessity of evacuating industrial

[1] C.S.D./Gen./62. [2] M.C. 100. [3] D.D.G.(C.)/C.M.G./291/3.

premises, brickworks, etc., which were required for ordinary occupation. These obvious problems had all been foreseen and a committee had been appointed as early as April, 1918, from the principal Government Departments concerned, including the War Office, Admiralty, Air Board, Board of Trade, Office of Works and the Ministries of Munitions, Shipping, Food and Reconstruction to consider the necessary action from this point of view.[1] By the end of 1918 there was no further capacity available except at the national factories, and in utilising these as stores the Ministry encountered opposition from the Treasury, who were anxious for rapid liquidation, and from the public who demanded their disposal to afford employment. Nevertheless, as the commercial value of these properties would probably increase for the next two years it was decided to delay the disposal of those not urgently required, while at the same time new transit sheds were erected.[2]

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[1] C.R.V./Gen./1907.
[2] D.B./S./22.

CHAPTER IV

SALVAGE AND SCRAP.

I. The Growing Importance of Salvage and Scrap.

The control of scrap metals and the salvage of finished munitions were two important factors in the general problem of economy of materials and munitions, the solution of which was forced upon Great Britain during the war. The extreme difficulty of providing equipment for the rapidly growing armies made salvage an important question from the outset, for it was one of the few measures possible, yielding immediate results in increased supplies. On the other hand, the question of dealing efficiently with the metal scrap resulting from munition making and other engineering processes remained in the background during the early years of the war, being dwarfed by the more pressing problems of production, and it was not until the end of 1916, when the shortage of material was becoming marked, and worse things were threatened by the ruthless submarine campaign, that the scrap arising from shell manufacture and scattered throughout the country in the shape of disused plant, tools and waste material was recognised as a vital source of metal supply, and the spasmodic efforts of the various supply departments to retrieve this scrap were co-ordinated and extended.

During the earlier stages of the war the amount of preventable waste of equipment was not excessive owing to the high degree of training and discipline in the original Expeditionary Force. But as time went on the officers and men of the new formations lacked sufficient knowledge of the importance of a sound system of economy, while discipline failed to reach the standard necessary to ensure the conscientious performance of such fatigue duties as salvage collection. The net wastage of rifles alone in the summer of 1915 was calculated at a rate which nearly equalled that of production. The increasing difficulty of equipping the growing armies made economy daily more urgent, and a special Salvage Organisation was formed to supplement the efforts of the troops themselves. At first a Divisional Organisation was all that was required, but during the Somme battles in 1916, the death roll and the expenditure of ammunition were far in excess of anything that had previously taken place. The ground over which the troops advanced was littered with rifles, steel helmets, clothing, cartridge cases, live ammunition and every conceivable form of equipment. At the request of the Ministry, steps were taken by the Army to increase the Salvage Organisations and to impress on each individual soldier the reasons why salvage had become such an important factor in the successful prosecution of the war. Salvage was then made a Corps Organisation, Corps Salvage Companies consisting of about 40 men being formed under the Corps Salvage Officer. The retirement of the Germans in the spring of 1917, from the positions which they had occupied throughout the winter

introduced an entirely new factor into the problem of salvage. The battlefields of 1916, in addition to thousands of tons of brass cartridge cases, empty shrapnel bodies, small arms ammunition and other ordnance stores, contained in the dug outs and mine galleries enormous quantities of Royal Engineer stores such as timber and other materials, which could then be dismantled and utilised. If this vast bulk of material was brought into circulation it would save not only the cost, but also the sea freight and a large proportion of the transport and handling which the provision of new material would entail. To deal with this new situation an organisation was formed to undertake battlefield salvage and placed under a Controller of Salvage who worked directly under and was responsible to the Quartermaster-General. By the summer of 1917 the British Army possessed a very efficient Salvage Organisation.[1]

The recovery of salvage from the battle area was, however, only one aspect of the problem. The best use of the material when regained was a problem of great difficulty, for the supply of components was often a bottle-neck in output, and it was not always easy to decide whether repair or dismemberment into "produce" was the most economical course with salved articles. Moreover, salvage was brought over irregularly, as transport facilities permitted.[2] This created difficulties at the ports of entry and salvage depots, and hampered the supply departments in arranging repair contracts and co-ordinating the supply of repaired articles with the normal supply of new stores.

It was with these aspects of the problem that the Ministry was called upon to deal on its formation in the summer of 1915. Throughout the war such salvaged articles as only required minor repairs were dealt with in France, and the repaired equipment was retained there for re-issue to reinforcements. All badly damaged or incomplete weapons and all surplus spare parts were shipped back to England, and under the Army system were sent to Woolwich or Weedon according to the nature of the store. As the amount of salved material increased, Woolwich became incapable of dealing with it all, and when the Ministry became responsible for munitions supply, steps were taken to increase the facilities for the repair and reception of salvaged stores, while the responsibility for the disposal of repairable material passed from Woolwich to the Ministry.

II. Salvage of Munitions.

(*a*) Departmental Organisation for Control.

In June, 1915, Sir Percy Girouard urged upon Mr. Lloyd George the importance of the establishment of a Salvage Department and the necessity for the careful selection of the staff of such an organisation.[3] He pointed out that technical knowledge was even more important

[1] C.R.4412.

[2] Salvage could be shipped from France only when the stocks of munitions there were up to the reserve. Otherwise the ships returned to England immediately without waiting to load up salvage.

[3] Hist. Rec./R./263.32/1.

than organising power, since the use of salvaged material involved also the whole question of dealing with scrap in large industrial firms, and was a highly technical business, far removed from merely sweeping up old and damaged material. Unfortunately, in the pressure of organising supply, this plan for organising salvage was not acted upon, and it was not until well on in 1917 that a system of a similarly far-reaching character was evolved.

At the outset, Mr. (later Sir Eric) Geddes, Deputy Director-General (C) in the Munitions Supply Department, was directed by the Minister to arrange for the utilisation of salved munitions in which the Ministry was concerned on their arrival from the various theatres of war,[1] and the Minister proposed that a special officer in Mr. Geddes' department should be detailed to co-operate with the War Office in this matter. In August, 1915, Captain A. U. Greer was appointed for this duty, and was made Director of the Salvage Section (C.M.4). This section was transferred in February, 1916, to Deputy Director-General (E)'s division of which it formed a part until, upon the formation of the Munitions Council in the autumn of 1917, Captain Greer's branch became an independent department (S.M.1) in the Finance Group.

From time to time, as was found necessary, salvage depots were formed at various ports, and in these depots the material was received and sorted. The responsibility for repair was vested in the supply departments of the Ministry, and the actual work was undertaken to a large extent by contractors as a subordinate part of their manufacturing programme, or in special repair factories set up by the different departments. At the end of 1916 the Ministry proposed that a liaison officer should be appointed to assist the War Office in dealing with salvage problems, and in January, 1917, this appointment was made.

Depots controlled by the Salvage Department had been established at Blyth, Dagenham, Ridham and Newport (Mon.)[2] When the Army Salvage Organisation was increased in the spring of 1917 the amounts of salvage returned became so great that during the summer serious congestion occurred at the ports. The existing depots were enlarged, and a new depot was opened at Immingham, near Grimsby, while arrangements were made for two more depots at Manchester and Glasgow.[3] Investigations made by the Surveyor-General of Supply, in the autumn of 1917, both in France and at home revealed that a considerable proportion of the excellent work done in France was wasted, owing to subsequent difficulties in transporting and disposing of materials not immediately re-usable for munitions manufacture. The arrangements for dealing with salvage in England were incomplete, and the Director of Salvage was experiencing great difficulty in getting the various supply departments to take over the salved materials. On the other hand, he was not always able to give them accurate estimates of the amount of repairable material available, which was essential

[1] M.W. 23339.

[2] For the details of the work done at these depots *see* Vol. VIII, Part II, p. 217.

[3] S.M. 1/169.

in order to enable them to arrange contracts, while much of the salvaged stores were of obsolete pattern, the re-use of which was difficult. Since the Ministry had been urgent in asking for the re-organisation of the Army Salvage Corps, and for tonnage for transporting salvage, such a state of things cast discredit on the Ministry, quite apart from the extravagance of the supply departments in using new material instead of facing the more difficult problem of utilising repairable salvaged goods.[1] Matters were complicated by the existence of a large dump for miscellaneous salvage at Richborough, a military port and area served by cross-channel barges, outside the organisation of the Salvage Department. Evacuation of this dump was peculiarly difficult as no civilian labour could be employed, and sorting proceeded so slowly in comparison with the accumulation of fresh material that, although the situation was viewed with alarm by the authorities in August, 1917,[2] it was not until November that an accurate estimate of the salvage there was provided for the use of supply departments.[3]

Towards the end of 1917 both the Army and Ministry salvage organisations were re-organised. All departments of the Ministry were instructed to give priority to salved and re-usable material before making use of new, and in November, Mr. (later Sir Alexander) Walker became controller of a combined Salvage and Stores Department in which Captain Greer was Deputy Controller in charge of salvage.[4] On the War Office side, the Surveyor-General of Supply devised a new organisation under a Salvage Board and Director of Salvage to link up departments already existing to deal with salvage. This plan left the organisation in France unaltered, but met the difficulty of transport and disposal by vesting in one section (Sal. 3), which took over all salvage at the shipping ports, responsibility for providing a definite destination for every class of material, for arranging for its shipment to the proper port in England, for landing it on its arrival, and distributing it to the various factories or depots where it was either repaired, stripped, converted into useful scrap or disposed of as useless for Army purposes.[5]

Up to this time the Ministry Salvage Department had dealt mainly with spent gun ammunition from which copper bands were recovered, and with cartridge cases and ammunition boxes. The scope of the department was now enlarged to enable it to deal with all salved material returned to the Ministry of Munitions, except guns and gun carriages. The Ministry was represented on the Army Salvage Board, and the Salvage Department instructed the Salvage Board as to the movement of such salved material as was originally supplied by the Ministry of Munitions. Salvage was taken on charge by the Salvage Department from the Port Forwarding Department, and sorted at the Department's depots, the quantities available being reported to the relative supply departments and forwarded by issue warrant in accordance with instructions received from the supply departments through the Central Stores Department.[6]

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[1] M.C. 244.
[2] S.M. 1/169.
[3] M.C. 456.
[4] *See* above, p. 49.
[5] HIST. REC./R./1370/2.
[6] General Memorandum, No. 48.

Enormous amounts of miscellaneous salvage were dealt with at the depots towards the end of the war. During the fourteen weeks immediately preceding the Armistice an average per week of over 5,000 tons of salvage was delivered from overseas, and of this over 3,000 tons per week was put into circulation for repair and re-issue.[1]

(*b*) GUN AMMUNITION COMPONENTS.

Cartridge cases were the most important item in the salvage of gun ammunition, and the return of these from the Front was regarded as a normal duty of the Royal Artillery. An 18-pdr. cartridge case can be re-formed six or eight times, and as each case weighs about 3 lbs., the possible net saving of metal by this means was large.[2] It was estimated that during 1916 about 59 per cent. of the 18-pdr. cartridge cases fired and about 41 per cent. of 4·5-in. howitzer cases were returned.[3]

Railway companies dealt with the re-forming of a number of cartridge cases, but in the spring of 1917 the improved conditions at the Front resulted in the return of such large quantities that additional re-forming plant became necessary. It was estimated in June that of the 18-pdr. cases fired, 70 per cent. were being returned, and of this quantity all could be re-formed with the exception of about 2 or 3 per cent. Cartridge case repairing plant was set up at the salvage depots at Newport and Dagenham, and both plants started work in July. At the end of the year the capacity of these two factories when working double shift was 500,000 and 250,000 per week respectively.[4]

The salvage of copper driving bands from shell was neglected during the first two years of the war. The removal of the band from a fired shell was a somewhat laborious operation for which special tools were necessary. The question of the salvage of these bands, either by removing them on the battlefield or by collecting the shell bodies complete and sending them to England, was raised at the end of 1916, owing to the enormous amount of spent shrapnel left on the battlefields after the Somme offensive. Tools for removing the bands were sent to France and proved very successful, and bands from the accumulation of fired proof shell at Shoeburyness were also removed for re-use at this time.[5]

Sample shrapnel bodies were also sent home in December 1916, in order that experiments might be made as to the possibility of re-forming them. The result of these experiments showed that very few spent shrapnel shell could be re-used, and that their only value was for melting down.

During the first two years of the war, the rectification of defective filled ammunition was carried out at Woolwich, but, by the summer of 1916, the capacity of the Ordnance Factory was no longer adequate to deal with the numbers of shell requiring rectification. Arrangements

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[1] HIST. REC./R./263/23.
[2] HIST. REC./R./1370/1.
[3] M.E.C./Gen./042.
[4] *See* also Vol. X, Part III ; HIST. REC./R./1800/40 ; HIST. REC./R./1370/3.
[5] M.E.C./Gen./042 ; HIST. REC./R./1800/40 ; C.I.S.P./Gen./526.

were made for the establishment of two Army Ordnance Factories in France, and accumulations in England were dealt with at Pembrey National Filling Factory. Rectification is a slow and laborious process and progress was disappointing. When the increased gun ammunition programme was adopted in October it was found impossible to continue rectification on a large scale.[1] As a result there was, at the beginning of 1918, a large accumulation of shell which had failed to pass inspection, or which was unserviceable owing to changes in design, and in February the Treasury sanctioned the scrapping of all deteriorated shell in cases where it was estimated that the cost of rectification would exceed 50 per cent. of the value of new shell.[2]

(*c*) Ammunition Boxes.

A box-repairing factory was started at Dagenham in connection with the salvage depot at the end of 1915. In January, 1917, evidence before the Metals and Materials Economy Committee suggested that only about a fifth of the ammunition boxes issued were being returned from France.[3] All those returned were filled with spent cases and no empty boxes were sent back. This was partly due to misunderstanding, as the return of all boxes was not at first asked for, and partly to the fact that empty boxes were being used by the troops to make paths and for firewood.[4]

The timber scarcity in 1917 made the salvage of all empty boxes, in addition to the metal-lined cartridge boxes, most urgent, and the re-organisation of Army salvage arrangements resulted in greatly increased supplies. In July, 1917, a box-repairing plant was set up at Newport, and at the end of the year this factory was capable, when working double shift, of dealing with 150,000 ammunition boxes a week, while Dagenham could deal with 60,000. By the time these factories were in working order the stock of 18-pdr. cases and boxes at the various stores in the country was so large that neither was ever called upon for full output. In addition a large amount of repair work was done by contractors, and by the National Box Factories, controlled by the Timber Supply Department. Boxes for bombs and grenades were dealt with at Beddington National Box Repair Factory, established early in 1917,[5] by the Trench Warfare Supply Department, which had also established various depots for the rectification of salved or defective trench warfare stores.

(*d*) Other Equipment.

Ordnance repairs, originally confined to Woolwich, were in 1916 also undertaken by the chief gun contractors, and in 1917 by certain of the National Shell-making Factories.[6] Damaged rifles were dealt with at Enfield throughout the war.[7] Repaired aero-engines were from the outset an important source of supply.[8] Many

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[1] Hist. Rec./H./1340/4.
[2] M.C. 508.
[3] Hist. Rec./R./1800/40.
[4] M.E.C./Gen./042.
[5] Hist. Rec./R./1370/3 ; Hist. Rec./R./263/23 ; Vol. XI., Part I.
[6] *See* Vol. X, Part I.
[7] *See* Vol. XI, Part IV.
[8] *See* Vol. XII, Part I.

were dealt with in the Engine Repair Depot at Pont de L'Arche in France, and at the Royal Aircraft Factory, Farnborough, and others by contractors under the direction of the Military Aeronautics Directorate, and later of the Department of Aircraft Production. Machine guns were repaired under the supervision of the Chief Inspector of Small Arms, and a few Vickers guns were repaired by the makers.[1] During 1917 the arrangements for the repair of machine guns were inadequate, the weekly average of guns made fit for re-use being almost negligible compared with those returned for repair.[2] This was due partly to the fact that about 50 per cent. of the guns returned were beyond repair, partly to the fact that it was the practice in France to strip guns of detachable components before sending them for repair, and partly to the limitations in the facilities of the Inspection Department for executing repairs. A great improvement resulted from the transfer of responsibility for repair from the Inspection Department to the Supply Department (November, 1917), and by the following December, Vickers and Hotchkiss guns were being repaired at the rate of 50 a week. Lewis guns were liable to much more serious damage than Vickers guns, and it was decided that there should be no attempt to repair them, serviceable parts being re-issued as spares.[3] Up to the end of 1916 practically nothing was being done as regarded salvaged small arms ammunition cases. In 1915 the Army in France was returning about 100 tons monthly, but on being notified that the material was not wanted at home, arrangements were made to sell all that was available to the French. Up to the end of October, 1916, about 1,000,000 kilogrammes had been handed over, but in consequence of the question of re-forming the ammunition having been taken up by the Metals and Materials Economy Committee at the end of 1916, the French were then asked to allow the shipment of some to England. It was estimated that about 12 tons a week could be sent home, though a greatly increased quantity could be made available if the collection were systematically undertaken.[4] In the spring of 1918 a large stock of salvaged and defective ammunition, much of which was American, was repaired by Messrs. Kynoch, and issued for use at a time when every round was urgently needed.[5]

Experiments were also carried out with the object of ascertaining whether impurities were added after the cartridge was fired, which prevented the metal being used again in the manufacture of small arms ammunition. The substitution of some explosive other than fulminate of mercury was also discussed, with a view to obviating the deterioration of the cartridge cases by the absorption of impurities. It was, however, decided that to re-form these cartridge cases was economically unprofitable, and since the brass would have its full value as such for casting purposes, there was no need for further investigation of any process for making the brass fit for cartridges. The salvage of the cases for remelting was recognised to be a very important matter.[6]

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[1] *See* Vol. XI, Part V.
[2] M.C. 154.
[3] M.C. 33.
[4] M.E.C./Gen./042.
[5] *See* Vol. XI, Part VI, Chap. V.
[6] HIST. REC./R./1800/40.

III. Utilisation and Control of Metal Scrap.

(*a*) Departmental Organisation.

The organisation for dealing with scrap was at first limited to a section formed in the Raw Materials Branch of the Gun Ammunition Department for disposing of the scrap metal arising from shell and fuse manufacture. For the purpose of dealing with non-ferrous scrap the country was, at the end of 1915, divided into three administrative areas, Birmingham, Manchester, and London. Birmingham being the centre of the brass trade, this area was the principal and most highly organised. A special accountant was appointed and made responsible for all metal received and issued. Technical experts were placed in charge of the mixing and grading of swarf, and the analysis of the metal resulting from remelting, the metal being received at a warehouse in Birmingham under the supervision of the Metal Accountant, where it was graded before being sent to the various firms for remelting. The Manchester and London areas were similarly organised, the collection in the London area being under the supervision of the Chief Engineer of the Metropolitan Munitions Committee.[1] A control order regulating the use and price of copper and brass scrap arising from munitions manufacture was issued in March, 1916, and a similar order for steel scrap in July, 1916. The Metal Buying Department (P.M. 1) arranged sales of scrap and surplus metal from Woolwich, but the Raw Materials Branch (A.M. 2) was generally consulted before sales were arranged, so that if the branch required metal scrap it could have it.[2]

The question of the more efficient use of swarf and scrap was raised by the Finance Committee on Economy in May, 1916,[3] but the technical questions involved had not then been sufficiently investigated, and administrative reorganisation was postponed until August. The Raw Materials Branch was then divided into two departments, one dealing with iron and steel production, and the other with non-ferrous metals and materials. Each had its own scrap section, but their operations were still confined to scrap arising from shell manufacture, or fired proof shell, and no steps were taken to secure adequate central control of all munitions metal scrap or the collection of reliable statistics and records.

When the Metals and Materials Economy Committee was appointed in November, 1916, "to advise upon the steps to be taken to secure the most economical use of metals and materials required for the manufacture of munitions," the recovery and re-use of swarf and scrap was immediately seen to be one of the most fruitful fields for economy. The price of brass and copper was at this time very high, and a large tonnage was absorbed and great indebtedness incurred in bringing supplies to this country. An extension of the methods of the Non-Ferrous Materials Department to include scrap from all sources seemed advisable. At the same time it was clear that the system of handling steel scrap was badly in need of reorganisation.

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[1] A.C. 47. [2] Hist. Rec./R./400/37. [3] Hist. Rec./R./400/37.

The Shell Manufacture Department was in charge of the experiments then being made in the use of scrap, but the Steel Production Department dealt with scrap disposal and controlled prices. There was no co-ordination between these two sections as to transporting the scrap to steel works and as to statistics of available scrap.

The committee proposed that a Director of Scrap Metals should be appointed, to devote his whole thought and energy to making available and economically handling the country's metal reserves. They thought he might well work under the general direction of and report through their own committee, and should, while helping all the supply departments, be independent of their control. His duties should be to ascertain what quantity of scrap would arise at Government factories and private works supplying Government Departments, to make sure that proper quantities were returned, and that the scrap was sent for treatment to such centres as were most economical both as to method of treatment and carriage, to see that no undue stocks accumulated, and that the means for treatment were adequate. They recommended also that the Director of Scrap Metals should create an organisation for purchasing parcels of old metal in every borough and at every country railway station.[1]

The whole question was referred early in January, 1917, to the Advisory Committee, which confirmed the necessity of appointing a Director of Scrap Metals, but recommended that he should only act in an advisory capacity with regard to the work already undertaken by the supply departments. His executive work should be rather in the direction of collecting scrap other than that obtained from munitions manufacture, and in organising the collection of old metal throughout the country, which was a duty outside the scope of existing organisations. Until all the scrap sections of the Department were in properly co-ordinated working order, it should be part of his duty to assure himself that scrap was not being held up in the munition factories, that transport facilities were obtained and that proper use was being made of scrap by the Steel Production Department.[2]

On 20 February, 1917, Mr. Alexander Walker was appointed as Director of Scrap Metals to perform the duties outlined by the Advisory Committee. He reported to the Minister through the Parliamentary Secretary, and at the same time was appointed a member of the Metals and Materials Economy Committee.[3] When in November, 1917, Mr. Walker was appointed Controller of Salvage and Stores,[4] his duties as Director of Scrap became merged in the larger office.

(*b*) NON-FERROUS SCRAP.

The machinery set up by the Raw Materials Branch at the end of 1915 for dealing with scrap metals was strictly confined to steel, copper and copper-alloy scrap arising from the manufacture of gun

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[1] A.C. 47
[2] *Ibid.*
[3] General Office Notice, No. 101.
[4] *See* above, p. 50.

ammunition. The first Control Order[1] was issued in March, 1916, when all firms engaged on munitions work were notified that certain classes of swarf and scrap must be placed at the disposal of the Ministry, namely, (1) copper turnings from shell bands, (2) brass from the manufacture of cartridge metal, fuses, primers and shell components, and (3) common cold rolled brass.[2]

The metal was collected through the ordinary scrap dealers from whom the Ministry purchased it at a fixed price, selling it again at a fixed price which covered the cost of administration.[3] Arrangements were made with a number of firms to remelt the swarf into ingots of two qualities, one containing under 1 per cent. of lead and the other under 2 per cent. As swarf varied in its composition, considerable care was required in mixing it either with cartridge metal scrap and spelter, or with copper and spelter, to obtain the correct alloy.[4] The metal was issued by the Department in the form of swarf, scrap or ingot, according to the needs of the contractor. By the beginning of 1917, 1,500 tons of non-ferrous scrap was being dealt with per week, the total issue of brass for munition purposes being then about 4,500 tons a week.[5]

It had not at first been considered advisable to interfere with scrap obtained from sources other than munition factories, but towards the end of 1916 the price of brass, copper and other metals became so high that steps were taken to extend operations to include all swarf and scrap obtained from copper, brass and other non-ferrous metals. The system of checking receipts and deliveries, which was essential for complete control of the use of scrap, had not been attempted when partial control was first established in March, 1916, and arrangements had to be made to secure the necessary returns. With this end in view, Control Orders were issued for the various metals of the non-ferrous group, early in 1917.

An Order under the Defence of the Realm Act (1 January), by which the Minister took possession of all copper and copper scrap, enabled the Department to ensure that scrap copper was consumed in work of national importance immediately it was produced, with the greatest possible economy in transport.[6] Accumulations of copper scrap were discovered and forced into consumption. Monthly returns were obtained of the total quantity of scrap accumulated during the month, the amount used in the works producing it, and the balance available. This balance was, by the Order, placed at the disposal of the Ministry, and could only be moved by issue warrant sent from the Non-Ferrous Materials Supply Department. Firms who wished to use their own scrap had to obtain a permit from the Department. An Order issued in February controlled brass scrap in the same way as copper. This Order did not, however, include process scrap from cartridge manufacture.[7]

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[1] For copies of these Control Orders *see War Material Supplies Manual*, 31 May, 1918.
[2] A.C. 47.
[3] Hist. Rec./R./400/37.
[4] A.C. 47.
[5] *Ibid.*
[6] C.R.V./Gen./710.
[7] M.C. 104.

The price of lead scrap, which before the war was roughly 15 per cent. below the price of new metal, rose after the outbreak of war to 10 per cent. above. Since new lead could not be freely purchased, there was a great demand for lead scrap which was not controlled, and this resulted in a great waste of new lead. Under the Lead Order (2 February, 1917), dealing in any kind of lead was prohibited, except by licence from the Ministry. About 250 scrap dealers received licences to purchase, and instructions to whom to sell. The price of lead scrap was fixed at 10 per cent. below the price of new lead, and monthly returns were required from sellers, dealers and purchasers of scrap lead.[1]

Aluminium scrap and swarf was controlled in February, 1917. The producer of the scrap or swarf informed the Department of his stocks at the end of each month, and a permit was given him to dispose of his stocks to refiners nominated by the Ministry (10 in number). The refiner analysed and graded the scrap and paid the producer direct. Weekly returns were received from the refiners showing the amounts received and issued, and the balance on hand.

Similar Orders were issued controlling cupro-nickel scrap (9 March, 1917), spelter and zinc scrap (23 March, 1917), and tin and terneplate scrap (24 August, 1917).

Control of aluminium and cupro-nickel scrap was comparatively easy because the number of manufacturers and melting pots was small and returns could be assured. With copper, brass and zinc it was much more difficult, since the enormous number of melting pots and the quantity of floating scrap made it very difficult to establish an exact system of check. Pots for melting were registered and records kept ; inspectors were appointed to visit fuse makers' works to check returns, and to visit melting pots to check receipts and deliveries, and permits for the purchase of copper or spelter were only granted on the condition that swarf should not be disposed of except to the Ministry of Munitions at Ministry prices.[2]

To prevent any leakage of metal, it was necessary also to require munitions manufacturers to account for the full weight of metal supplied to them, either in the form of stores or scrap. Mr. Rothschild had raised this point in February, 1916, before the Finance Committee on Economy,[3] but the control organisation was not then sufficiently developed to make this practicable. The Minister's Advisory Committee also emphasised the necessity for such returns in January, 1917,[4] and the Contracts Department made the necessary arrangements with regard to cartridge metal. Similar steps for checking the metal used in fuse-making were delayed until June, owing to the difficulty of establishing a system of records and inspection,[5] but thereafter contracts were arranged whereby the actual weight of metal delivered to the fuse manufacturer was to be delivered by him in fuses and scrap (less a small percentage as agreed), any deficit being charged at a price considerably in excess of the market value of the metal. It was specially important

[1] HIST. REC./R./1810/71 ; M.C. 104.
[2] M.E.C./Gen./016.
[3] HIST. REC./R./400/37.
[4] A.C. 47.
[5] M.E.C./Gen./026.

to keep a strict account of material supplied to Switzerland, which was making 28 per cent. of the British fuse requirements for the first six months of 1917, to prevent the escape of swarf to Germany at famine prices, and it was thought that the accounts of material received and fuses and swarf delivered ought to balance within 3 per cent.[1]

By September, 1917, control had been extended to practically all scrap metal, and the systems of check were in working order. In some cases great savings of metal were effected. Within a few months after the passing of the Copper Scrap Control Order some 2,000 tons of scrap metal per month became available, and the saving of virgin metal thereby effected formed the basis of the creation of a reserve stock.[2] Experts were engaged by the Department to visit and educate manufacturers in the use of brass scrap, and a large number of firms were persuaded to use various qualities of scrap, where in the past they would use only virgin metal. In one or two cases firms were induced to apply new processes of manufacture in order to make use of low quality scrap.[3]

(*c*) Ferrous Scrap.

Steel scrap produced in munitions manufacture was classified under two headings, as steel of known analysis, and as mixed scrap, the analysis of which could not be guaranteed. The scrap arose in four forms (1) turnings and borings, (2) heavy scrap, (3) rejected forgings, (4) rejected machined parts.

At the end of 1916, it was found that the control of ferrous scrap had not been organised so effectively as that of non-ferrous scrap. This was partly due to the fact that control was divided between the Gun Ammunition Department and the Steel Production Department, and partly to the fact that a good deal of experiment was necessary before the best use of the scrap and swarf could be found. This latter point was taken up by the Finance Committee on Economy in May, 1916.[4] At the end of the year it was reported that satisfactory pig for foundry purposes had resulted from melting 50 per cent. scrap and 50 per cent. pig in a cupola furnace. In an ordinary open hearth furnace 15 to 20 per cent. appeared to be the maximun proportion of scrap which could be used in the loose form, but in the briquetted form the use of 50 per cent. was possible.

The Shell Manufacture Department had already taken up the subject of briquetting, and a section for supervising the erection of briquetting plant had been formed in A.M.3. The use of electric furnaces for dealing with scrap had also been considered. The efforts of this department had been handicapped because the Steel Production Department exercised some control over disposal, and occasionally authorised shell manufacturers to dispose of their scrap direct. The Shell Manufacture Department therefore urged that they should have complete control of

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[1] M.E.C./Gen./016.
[2] *See* Vol. VII, Part III, Chap. II.
[3] M.C. 104.
[4] Hist. Rec./R./400/37.

all shell scrap until it reached the steel makers' premises where it was to be remelted. They also contended that a great abuse had been created in July, 1916, when the maximum price for steel scrap of " unknown analysis " had been fixed at £5/15/0 per ton. Certain scrap dealers were purchasing scrap at this low price, knowing that the analysis varied very slightly from the guaranteed analysis, and were selling it with a guaranteed analysis at prices ranging up to £10 per ton. To prevent such malpractices as this, which arose from divided and incomplete control, the Shell Manufacture Department wished to assume all responsibility for collecting returns of available scrap for dealing suitably with it after collection and for arranging for its disposal at fixed prices to the steel makers indicated by the Steel Production Department. This proposal was not endorsed by the Advisory Committee, which recommended (January, 1917) that the Director of Steel Production should be responsible for collecting scrap, providing transport and delivering it at steel works,[1] the responsibility of the Controller of Shell Manufacture being limited to treating the scrap so as to enable the Steel Production Department to use it to the best advantage. The Director of Steel Production, the Controller of Shell Manufacture, the Director of Scrap Metals and the Director of Area Organisation were instructed to confer with a view to perfecting a system of dealing with scrap at munitions works, and the Controller of Shell Manufacture and the Director of Area Organisation were to supply returns of stocks of scrap and monthly forecasts of output. The position at this date (January, 1917) was that only part of the scrap from munitions or government factories was being passed over direct to the Steel Production Department to handle. The bulk of it found its way through the hands of dealers, or where the munitions factory had been combined with shell steel works belonging to the same firm, it had been used direct ; and it was admitted that the total percentage of steel which through this leakage was not accounted for, was very considerable.[2] This state of affairs had arisen because the Steel Production Department was awaiting the completion of the experiments on briquetting borings and turnings from shell manufacture, before pressing the use of scrap to its utmost extent, and there was a large accumulation of scrap in consequence,[3] in spite of the fact that there was less steel scrap than usual available from shipbreaking and ordinary engineering work.

The Advisory Committee had felt that if necessary the Director of Scrap Metals should have power to enforce the use of the proper quota of scrap by steel makers, as it was certain some were not using scrap to the fullest possible extent. Though experiments were being continued there was still no well-defined policy as to how best to treat the scrap, what proportions could be used in an open hearth or other furnace, or whether it was advisable to use it in the blast furnace. The priority system was applied so far as was possible, to induce substitution of shell discard for mild steel, but this could only be done by pressure from the Priority Committee upon particular steel makers,[4] and no

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[1] A.C. 47.
[2] *Ibid.*
[3] HIST. REC./R./1800/40 ; A.C. 47.
[4] HIST. REC./R./1810/71.

authority existed for enforcing the use of scrap. The Director of Steel Production deprecated any attempt to hamper the steel works by introducing compulsion, but, assisted by the Director of Scrap Metals, the Area Organisation Department and the Boards of Management, was able, by peaceful persuasion, to increase the use of scrap, so that by August most of the accumulations existing in February had been absorbed. As a result of this pressure from the Department steel makers were induced to increase the proportion of scrap up to 50 per cent. of the charge.[1] Each firm was requested to make a return of the proportions of pig iron and scrap used, and those using only a small percentage of scrap were dealt with individually, and a considerable saving in pig iron was effected.[2] As the steel makers became accustomed to using scrap, the steel furnaces began to compete with the blast furnaces, which before had been the only outlet for scrap, for steel scrap of all kinds.

From the beginning of 1917 onwards, the Steel Production Department took over responsibility for the collection and transport of steel borings and turnings, defective forgings and other scrap, and, under the direction of this department, national factories and other shell makers sent their scrap to the nearest steel works. Sales were no longer made to merchants, except where the material was collected in very small quantities.[3]

(*d*) Miscellaneous Scrap.

The chief duty assigned to the Director of Scrap Metals, on his appointment in February, 1917, had been to form an estimate of the amount of scrap of all kinds which could be obtained from sources other than the manufacture of munitions, and to arrange for its collection. This scrap divided itself into two classes, domestic scrap, consisting mainly of old brass and empty tins, and commercial scrap, such as obsolete machinery and plant of all kinds.[4]

The result of Mr. Walker's investigations was embodied in a report dated 14 March, 1917. He found that the scrap metal trade was in the hands of (1) small collectors who collected miscellaneous material as economically as could be done by any other agency, (2) dealers who bought in bulk from the small collectors, and also purchased old ships, dismantling of factories, salvage from fires, etc., and had regular contracts with large firms and government factories to remove scrap. These firms had staffs of experienced sorters, but the normal flow through these channels had been checked by the calling up of sorters and small collectors, and it was difficult to get the scrap sorted and broken and bundled for transport.

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[1] Hist. Rec./R./1800/39. It is probable that the amount of scrap used by steel makers prior to the war did not exceed 30 per cent. of the charge, and in many cases was as low as 10 to 15 per cent.

[2] F. H. Hatch. *The Iron and Steel Industry of the United Kingdom under War Conditions*, p. 32.

[3] C.I.S.P./Gen./526.

[4] A.C. 96.

He had found some difficulty in forming an estimate of the reserves of material existing in these forms, partly owing to the fact that firms busily engaged in production were reluctant to face the trouble of making inventories, and partly to the fact that firms were holding scrap and obsolete machinery as a hidden reserve for realisation after the war, when it was expected that these assets could be sold, without the proceeds being subject to excess profits duty. He recommended, therefore, that a compulsory return of all scrap and obsolete plant should be demanded, and that the scheme should be worked through the local Boards of Management. He thought that if a statement of scrap values were issued, the price of aluminium, brass, copper, lead and phosphor bronze would offer a tempting opportunity to scrap all plant and utensils containing these metals.[1]

A sub-committee of the Advisory Committee was appointed to consider his report. They were of opinion that since the chief difficulty in the way of making the scrap available was the shortage of labour and transport, a scheme for compulsory acquisition would not serve any useful purpose. They recommended that letters should be sent to selected firms pointing out the necessity of bringing all scrap into the market, and that a press campaign to the same effect should be started. They thought that representatives of the Director of Scrap Metals might be attached to Boards of Management to advise firms, and that the Director should report from time to time on the success of the appeal. It was agreed that the Director should work out this scheme area by area, putting it in force in the first instance in the South Western (including South Wales) and Glasgow districts, where it was known that basic steel furnaces could absorb large quantities of scrap. These recommendations were accepted by the Minister in June, 1917, but subsequently the Director of Steel Production opposed the scheme as he did not think it possible to absorb all the scrap metal which would result. Consequently, the scheme was confined to the South Western District until experience had been gained.[2]

Eventually, the Director of Scrap Metals abandoned the press campaign, but obtained the gradual release and absorption through foundries and steel furnaces of dormant commercial scrap by a system of canvassing. Officers were appointed for the London, South Wales and Lancashire areas. An experiment in the collection of domestic scrap carried out on behalf of the Red Cross did not prove successful enough to justify its extension. Another possible source of supply—the naval yards—was considered, but on visiting Chatham and Portsmouth Mr. Walker found no large accumulations of scrap, and was able to make arrangements with the Admiralty and War Office and at Woolwich for the clearance of what there was.

The great obstacle to mobilising scrap in the form of obsolete plant was the difficulty of breaking it up into a form suitable for transport and use in the furnaces. The smaller scrap merchants who, owing to the shortage of ordinary scrap, were more than usually energetic in seeking out supplies, were unable to deal with this type,

[1] A.C. 96. [2] *Ibid.*

since special machinery and labour were required. The shortage of oxygen was another difficulty in securing boiler scrap and heavy pieces, which could not be broken by hand labour.[1]

Though much was done during the summer of 1917 towards making effective use of the country's resources in scrap metals, the Minister was not yet satisfied that everything possible was being done to ensure the utilisation of all that was available. A Council Committee considered the subject once more in September, 1917, and came to the conclusion that the chief source hitherto not fully exploited was to be found in accumulations of obsolete plant.[2]

In December, Mr. Walker made another report on the situation to show how far the reduction of importation of ore during 1918 might be made up from the dormant resources of the country and by salvage from the war area. His estimate showed that obsolete plant and machinery were the largest source of supply. A high price would have to be given to obtain any large quantity, and compulsory powers would probably be necessary. Against this was to be set the advantage to the country of scrapping all inefficient machinery as a reconstruction measure, since this class of machinery, incapable of economic production, had been the bane of our industrial system before the war, and its destruction would create a demand for up-to-date plant.[3] Compulsory seizure of plant would involve an organisation for valuation, the arrangement of labour supply and supplies of oxygen and carbide or their alternatives. Experienced cutters would have to be brought back from the Army or men would have to be trained. Compulsory acquisition in fact implied setting up a Ministry organisation, preferably decentralised in the areas; it would be a most expensive means of getting scrap, and would only be justified, in Mr. Walker's opinion, by a grave national emergency. Compulsion, therefore, was again postponed. But the shortage of metal became very serious in the spring of 1918, and a scheme for acquiring dormant scrap by compulsion, and for purchasing obsolete plant for scrap purposes was adopted on 9 May.[4] An Order was issued on 20 August, requiring the sale of all iron and steel scrap, whether in the form of metal, machinery, plant or constructional steel or ironwork, when required by the Controller of Salvage and Stores. The Order as at first drafted in March, had included obsolete machinery and plant incapable of further use as a productive agent, but it was later considered advisable to deal with obsolete plant purely by negotiation, and this part of the draft Order was deleted. But by the time this far-reaching scheme came into practical operation the end of the war was in sight.[5]

It has been seen above that the scheme for collecting domestic scrap did not meet with the success expected, but it had one important outcome in the development of the use of old tin scrap. By August,

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[1] Hist. Rec./R./1800/39.
[2] Hist. Rec./R./1800/37.
[3] Hist. Rec./R./1810/55. It was, however, pointed out that this plant might have high value in emergencies. (C.I.S.P./Gen./526).
[4] C.I.S.P./Gen./526.
[5] C.R.V./Gen./2362.

1917, works were turning out a large tonnage of steel per week by detinning clean tin strip and other processes, and at the end of the year recovery of steel scrap from this source was about 8,000 tons per cent. The return of tins from France opened up a large source of supply of material for this process, and arrangements were made to supply scrap in this form to the French Government, who were understood to have facilities for disposing of all that could be supplied to them. At the end of 1917 approximately £8 per ton could be realised by buyers of tin scrap for treatment by the Goldschmidt process.[1]

The efforts of the Ministry to make use of salvage from the battlefields and scrap from the factories increased with the growing difficulty in providing material for munitions production. The results attained in most cases justified amply the establishment of the various organisations which were set up for this purpose.

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[1] HIST. REC./R./1800/39; HIST REC./R./1810/55; C.I.S.P./Gen./526; HIST. REC./R./1370/2.

APPENDIX.

(CHAPTER I.)

Chief Imports of Munitions and Munitions Materials, 1915-1918.[1]

	U.S.A.	Canada.	France, Spain and Mediterranean.	Northern Europe.	South America.	Australasia.	India and Straits.	S. E.&W. Africa.	China and Japan.	Other Countries	Total.
Finished Munitions[2] ..	1,025,733	1,425,463	71,323	—	—	24	9,828	—	—	—	2,532,371
Iron Ore	—	—	23,060,798	2,610,554	—	—	—	—	—	179,017	25,850,369
Other Ores	—	—	212,024	—	14,515	—	1,469,918	—	—	3,545	1,700,002
Ferrous Metals[3] ..	3,608,193	288,998	27,749	576,703	—	1,497	—	—	—	20,905	4,524,045
Non-Ferrous Metals[4]	1,099,287	95,753	951,489	147,772	282,455	543,133	209,810	230,127	94,425	179,804	3,834,055
Explosives & Materials[5]	528,811	70,790	4,756,047	338,518	1,450,050	—	86,916	12,026	—	45,248	7,288,406
Railway Materials ..	107,312	121,136	—	4,235	—	86	—	—	—	4,100	236,869
Mechanical Transport	81,980	—	—	—	—	—	—	—	—	—	81,980
Machine Tools ..	117,321	46	37	329	—	—	—	—	—	240	117,973
Agricultural Machinery	112,094	22,960	235	1,898	—	—	—	—	—	180	137,367
GRAND TOTAL ..	6,680,731	2,025,146	29,079,702	3,680,009	1,747,020	544,740	1,776,472	242,153	94,425	433,039	46,303,437

[1] Figures denote tons. In the case of railway materials and mechanical transport the figures are for 1916–18.
[2] Includes guns, small arms, ammunition (of all kinds) and shell components.
[3] Includes shell steel and forgings, general steel, pig iron and ferro-silicon.
[4] Includes aluminium, bauxite, copper, lead, spelter, zinc concentrates, nickel, tin, etc.
[5] Includes N.C.T., cordite, T.N.T., nitrates, pyrites, phosphate rock, sulphur, wood distillation products, etc.

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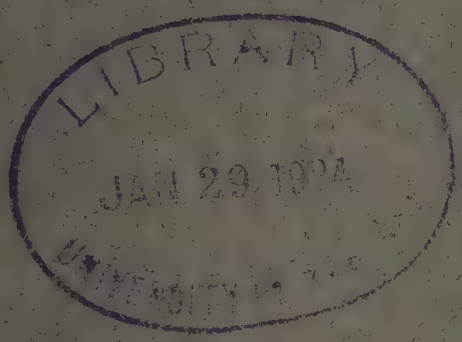
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VOLUME VIII

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PART I

REVIEW OF STATE MANUFACTURE

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CHAPTER I.

THE ROYAL ORDNANCE FACTORIES.[1]

At the outbreak of war, State manufacture of munitions was already a long established fact. In August, 1914, it was being carried out at the Royal Ordnance Factories and at the Royal Aircraft Factory, Farnborough. The Royal Ordnance Factories consisted of (1) a Small Arms Factory at Enfield where rifles, bayonets, swords and similar articles were being produced and machine guns repaired, (2) the Gunpowder Factory at Waltham Abbey, which was making cordite, tetryl and small quantities of fuse compositions, and (3) a group of factories at Woolwich, which produced guns, shells and practically every other class of munition and, together with other establishments concerned with inspection, stores, research and instruction, formed the Woolwich Arsenal.

I. Functions of an Ordnance Factory.

Before proceeding to give some account of the development of the Ordnance Factories and to show with what measure of success they fulfilled during the war the functions for which they were designed, it will be well to summarise briefly what those functions were.

Various considerations may be urged in favour of the State manufacture of munitions. The ordinary laws of supply and demand do not apply in the case of the most costly and important munitions of war, the sources of supply being strictly limited, and effective competition non-existent. The ability of the State to manufacture for itself may be in such cases very important in arriving at fair prices, while for stores, in the manufacture of which more normal conditions obtain, the cost of production in a State factory may form a valuable check on trade prices. Some such establishment seems essential, as a source of the specialised knowledge of manufacture required for government inspection and control, and as a headquarters for the improvement of design, as well as for the establishment of a standard of excellence in workmanship. From the point of view of economy the execution of repairs by a State factory has many advantages, since it is very difficult to gauge beforehand the amount of repairs required, or to check the cost of repairs done under contract, while it is of value that repair work should be undertaken in the factory which is most closely in touch with design, in order that failures and weak construction should be brought to the immediate notice of designers. Secrecy, which is often essential in armament development, is more easily attained in a government factory.

Collation of designs from all sources was regarded in 1917 as a special function of an Ordnance Factory, but experience at Farnborough showed that this might lead to jealousy on the part

[1] For a detailed account of the development and work of each of these factories during the war, see Vol. VIII, Part II, Chap. I.

of contractors and that collation of design was more properly the function of a special staff independent of manufacture. The special machinery and highly skilled personnel of a government factory are, however, invaluable for experimental work and the production of experimental stores, and all kinds of special stores which are required only in small quantities, while the same attributes are of value in enabling it to act as a balancing capacity for the production of urgent stores or making good the failures of other producers.

The aspect of a State Ordnance Factory which attracted most attention before the war was its power of providing a reserve of productive power in times of emergency. The experience of the war has, however, proved that no national arsenal is capable of dealing with the output needed for a European war. The magnitude of present-day warlike operations has shown that the real reserve for war is the whole of the manufacturing power of the country. Opinion as to the principal duty of an Ordnance Factory has accordingly changed, and though a State factory still requires a moderate expansive power to meet small wars on the frontiers of the Empire, its function as a centre of experience and knowledge from which instruction may be quickly propagated throughout the country has now assumed far greater importance. To fulfil this rôle the Arsenal should be experienced in the manufacture of every kind of warlike store, and have plant for their production, so that it may be in all cases relied upon for exact knowledge and experience in manufacture. Provision must be made for the training of personnel of new factories when expansion is suddenly required. The Arsenal should include equipment on a large scale for making gauges for issue to firms when emergency arises. It should also be in possession of complete knowledge of the manufacturing capacity of the country as a whole and should be given every opportunity of keeping that knowledge up to date.

II. Early Development of the Royal Ordnance Factories.

In order to form any adequate idea of the conditions existing at the Ordnance Factories on the outbreak of war, and to appreciate the effect of these conditions upon the development of the factories during the war, it is necessary to consider at some length their previous history. Both Woolwich Arsenal and the Royal Gunpowder Factory date from Tudor times, though the latter was not purchased by the State until 1787. The Royal Laboratory was moved in 1695 from Greenwich to Woolwich, where there were also in 1717 a foundry for brass ordnance, yards for building gun carriages, a shot house and powder house, a proof yard, carcase barn and firework house. Woolwich became the headquarters of the Royal Artillery about 1719, and in 1741 a school of instruction for gunners—the Royal Military Academy—was established there. The ordnance stores were transferred from the Tower of London to Woolwich about 1800, but it was not until 1805 that the whole collection of these establishments received the name of the Royal Arsenal. At the same time (1804) the nucleus of the Royal Small Arms Factory was established at

Enfield. In the years that followed the close of the Napoleonic wars, the State establishments for making munitions were neglected. Shortly before the outbreak of the Crimean War a plan was set on foot for making small arms by machinery in a single State factory of unprecedented size; but the project was reduced, mainly by reason of its cost, to an extension of the Enfield factory, while the Crimean war itself proved that the Woolwich factories were inadequate for their purpose. As a result they were reorganised and modernised. A shell factory was built in 1855 and a gun factory for the manufacture of the Armstrong rifled gun in 1856–8. Several hundreds of women were employed in making cartridges until 1872 when, for reasons of social and economic well-being, they were all dismissed. In the same year the Arsenal was enlarged by the inclusion of the former naval dockyard, which had been closed since 1869.

(*a*) Pre-War Administration.

The Royal Ordnance Factories consisted in 1886 of five manufacturing departments, the Gun Factory, the Carriage Factory and the Royal Laboratory at Woolwich, where guns, carriages and ammunition of all kinds were made, Enfield and Birmingham Small Arms Factories, and Waltham Abbey, where gunpowder of all kinds was then manufactured. Each of these five departments was under a military superintendent with a civilian manager acting under him. Each department was entirely independent of the rest, and the military superintendents had supreme control of the factory under them, and a free hand in its administration provided they did not spend more money than the amount allotted to them. The superintendents, who were appointed for five years only, were responsible through the Director of Artillery and Stores to the Surveyor-General of Ordnance. Each factory designed the articles which it manufactured in drawing offices under the control of the managers. The departments also tested and passed their own manufactures as well as the articles manufactured by the trade, with the exception of gunpowder, that for ordnance being proved at the Gun Factory and that for small arms ammunition at the Royal Laboratory. The superintendents and managers decided what tests should be applied to all the articles they manufactured with the exception of steel forgings, the tests for which were framed on the recommendation of the Ordnance Committee.

Stores for all the manufacturing departments were bought by the Director of Contracts, usually by a system of limited tender, a few firms only being asked to tender for the articles required. The reason for this limitation was that the superintendents of the factories, when they sent their requisitions to the Director of Contracts, usually recommended the firms that should be invited to tender, and though the Director of Contracts had power to add to the number of firms recommended, he did not usually exercise that power against the judgment of the manufacturer who had technical knowledge. The superintendents had a limited power of purchasing small articles without reference to the War Office.

All orders were given to the departments through the Commissary General of Ordnance in the form of what were technically termed "extracts," viz., extracts from letters addressed to the Commissary General by the Director of Artillery and Stores. Small arms alone were excluded from his action, orders going to Enfield through the Ordnance Store Officer at Weedon. In addition to the consolidated demands for the whole year, there was an enormous number of supplementary demands, no less than 4,000 extracts being issued to the manufacturing departments during 1886.

It was clear that in 1886 the administration of the Ordnance Factories was not sufficiently centralised. The Director of Artillery and Stores, the nominal head of all the factories, was too much occupied with other duties to exercise effective supervision or to harmonise the work of the various factories. Grave practical difficulties were the result. For instance, changes in the design of guns which affected the gun carriages were made by the Gun Factory without informing the Carriage Factory, which continued to manufacture to the old design until practical experience disclosed the error.

The necessity that the officials in charge of the manufacture of warlike stores should have practical knowledge of their use was recognised throughout the history of Woolwich. The military staff was selected almost entirely from the Royal Artillery, and to qualify for appointments to the manufacturing departments, candidates had to pass through the senior class of the Artillery College, and before taking this course, six years' military service was necessary. Under the superintendents of factories there were assistant superintendents, captain inspectors, and captain instructors, the latter being in charge of the numerous officers and non-commissioned officers who received instruction in the Arsenal. The superintendents were usually appointed from the ranks of the assistants. The managers were invariably civilians, and had the direction of manufacturing operations.

A committee appointed in 1886, under the chairmanship of Lord Morley, to consider the administration of the Ordnance Factories, reported that the constant breaks in continuity of management due to the quinquennial changes of superintendent were a drawback and that those directly responsible for administration should hold office at the pleasure of the Secretary of State. They also raised the question of the advisability of having military men in charge of the administration of the factories, since it did not appear that a military career gave opportunities for acquiring a knowledge of factory organisation and manufacturing processes. It seemed to the committee that this, combined with the quinquennial changes, placed the superintendents too much in the hands of their civilian managers. The chief argument in favour of the limitation of these posts to military officers was that military experience was of the greatest value in designing and inspecting munitions; but it was pointed out that such experience was not required in manufacturing articles to conform to a given pattern and to stand defined tests. In these operations other qualities, such as capacity for organisation and knowledge of manufacturing processes and materials, were more important, and were more generally

acquired in civilian than in military life. Provided, therefore, that the military element was always present in the designing and inspecting branches, the committee recommended that for the superintending of actual manufacture the best available men should be selected, and they held that under the existing conditions the field of selection was restricted within dangerously narrow limits.

In order to secure co-operation between the different factories, the committee proposed to place them all under one Superintendent of Ordnance Factories who should be of military rank. The main object of the committee was to separate design and instruction—the military side, from manufacture—the civilian side, and with this object in view they advised that the Superintendent, for the performance of his duties connected with general superintendence, design and experiment, should be assisted by officers, who together with the instructors, should form his permanent staff, while directly responsible to him for manufacturing arrangements there should be a Chief Mechanical Engineer, a civilian, whose assistants—also civilians—would be managers of the various factories. Since in accordance with War Office procedure the Superintendent could be appointed only for five years, they recommended that he should be reappointed at the discretion of the Secretary of State. In view of the distance of Waltham and Enfield from Woolwich it seemed advisable to have superintendents for each of these factories who should report to the Chief Superintendent. This arrangement seemed to lose sight of the fact that the reserve from which to draw the Chief Superintendent and inspecting staff would soon disappear owing to the complete failure to provide a supply of military officers with previous training in actual manufacture.

These recommendations were carried out to a limited extent only. The administration of the Ordnance Factories was centralised under a Director-General, not necessarily a military officer, reporting to the Financial Secretary, and a separate Department of Inspection was created at the Arsenal and placed under the Director of Artillery, who reported to the Commander-in-Chief, the office of Surveyor-General of Ordnance having been abolished. The factories thus lost the duty of inspecting trade products, but they retained certain inspection duties in respect to their own. The recommendations with regard to the appointment of a Chief Mechanical Engineer were not carried out, and military officers remained as superintendents of the various factories, the five year limit of their appointments being abolished soon after. The reasons given for the elimination of the military element did not seem to be justified, as the organisation of labour was good, and the cost of production was low.

Subsequent changes in the administrative control of the factories by the War Office had little effect on their immediate administration, which remained under a single Chief, whose title was altered in 1899 to Chief Superintendent of Ordnance Factories. In August, 1914, section A4 in the department of the Director of Artillery, was responsible for the personnel of the Ordnance Factories as well as for the Inspection Department.

The reorganisation of the Ordnance Factories was decided on in 1887 and was mainly carried out by Sir William Anderson, who held the post of Director-General of Ordnance Factories from 1889. A central office was established, through which all communications between the factories, the War Office and the Admiralty were to pass, and the work of the stores, cashiers and works accounts branches was transferred thither. The Chief Superintendent was assisted at the central office by a secretary who dealt with all technical questions, and a civil assistant responsible for the stores, finance, works accounts and pay branches; but each superintendent still retained his own office with its own system of registration, its own copies of all correspondence, and its own drawing and designing offices. This extremely limited centralisation was partly due to the decision to retain the factory superintendents, who naturally wished to maintain their independence as far as possible, and partly to the impossibility, owing to the lay-out of the Arsenal, of providing sufficient accommodation in the central offices. Rooms had been provided there for the superintendents, but not for their staffs, with the result that a superintendent, when in touch with the Chief Superintendent and the central registry, was out of touch with his own staff, with which the greater part of his work was carried out, and the superintendents soon ceased to use the accommodation provided for them in the central offices. The central registry was insufficiently accessible for any separate factory to rely on it for reference, consequently each factory maintained its own registry, though the only strictly clerical duty remaining in the province of the factory superintendents was the preparation of the wages accounts. This state of things was altered after 1902 by the provision of offices for the Chief Superintendent and the factory superintendents in a new building, centrally placed, and a set of records was established there for general use.

A certain amount of concentration was effected by readjustment of work between the factories. Each was in 1887 completely equipped for the production of those classes of stores with which it dealt. Each had its own foundries, forges, railway engines and rolling stock, but during the next ten years nearly all wood-work was concentrated in the Carriage Department and a boiler repairing shop for all the factories was opened in the Gun Factory. At the same time the departments were encouraged to make the freest possible use of each others' workshop resources.

Up to 1888 an officer of the Royal Engineer Department, stationed at Woolwich Arsenal and known as the Inspector of Works, was in charge of building and various engineer services for the Ordnance Factories and other departments of the Arsenal. In 1888 his title was changed to Superintendent of Building Works, and he became the subordinate of the newly appointed Director-General of Ordnance Factories, holding his appointment at the pleasure of the Secretary of State. To him were transferred the general Arsenal services, such as the gas factory, the railways, hydraulic establishments, telegraph, telephone and coaling arrangements and a central electric station, which replaced the electric lighting plants which were beginning to

grow up independently in the several factories. The separate store branches of the factories were centralised, the store branch of the central office holding and issuing materials for all Arsenal factories and the Building Works Department. At Woolwich many stores were delivered direct to the factories, only passing through store on paper; those which actually passed into the custody of the Central Stores Department were kept in buildings which were formerly the storehouses of the several factories, the centralisation being in the main administrative. No site was available for a central store, even had such been desirable from the point of view of convenience in distribution. The introduction in 1888 of a separate vote for the Ordnance Factories as a whole made it necessary to go a step further and to centralise at Woolwich the general administration of the outlying factories, though stores were delivered direct to those factories and held and issued by their superintendents.

It was Sir William Anderson's wish to carry centralisation very much further and to amalgamate all the factories as proposed by Lord Morley's committee. He also planned a revision of the lay-out of the Arsenal, but this did not materialise in his lifetime, and by 1901, the policy of retaining the services of superintendents in charge of the manufacturing departments became quite clearly defined. His successor, Sir Frederick Donaldson, revived the question of the unsuitability of the lay-out and equipment of the Arsenal, but the difficulties of reorganisation were enormous, and the only result was a grant of £175,000 for machinery spread over three years under conditions which went a long way towards defeating the object in view.

In the early part of 1909 the Royal Gunpowder Factory at Waltham and the Royal Small Arms Factory at Enfield were removed from the control of the Chief Superintendent of Ordnance Factories and placed under the charge of a single head known as Superintendent of Waltham and Enfield. Accounts for Waltham and Enfield were still kept at Woolwich, but there were three separate offices at Waltham and Enfield, one for each factory, and one for the Building Works Department. These offices were centralised when the superintendence of the two factories was united. In October, 1917, the factories were once more separated and placed under separate superintendents, as conditions were so different in the two factories, the work in one being of a highly skilled mechanical nature and the other entailing special knowledge of explosives, but no very special skill among the employees.

The policy whereby the Arsenal was the centre both of manufacture, inspection and storage, to a great extent for both Services, led to great congestion at Woolwich after the outbreak of war. The fact that filling of nearly all ammunition was carried out at Woolwich during the first eighteen months of the war added to the confusion, components from contractors passing into the Ordnance Stores and being issued to the filling factories as required. A stream of stores and components poured into Woolwich from all parts of the country and from the United States and Canada. At first these included all army stores whatsoever, but the formation of subsidiary stores diverted

a certain amount. Throughout the war, however, large stores were held at Woolwich both by the Deputy Director of Ordnance Stores and the Superintendent of Ordnance Stores, and added greatly to the difficulties of production there, whilst the presence of such large stocks of explosives and filled ammunition at the Arsenal very greatly increased the danger risks.

The recommendation of Lord Morley's committee with regard to design aimed at the centralisation of design within the Arsenal and the strengthening of the control of the Ordnance Committee. They advised that the Superintendent of the Ordnance Factories should be responsible for the initiation and elaboration of design, having under him a department in which should be concentrated the several drawing offices then distributed between the various factories. He should be aided by advisers from his own staff, the chemist of the War Department, the Chief Mechanical Engineer and such naval and military officers as he should, after consultation with the Director of Artillery and Stores, call to his assistance. The functions of the Superintendent under this head should be limited to such designs as were prepared in the manufacturing departments and he should not be in any way concerned with inventions or designs of private persons. Such designs, as well as those prepared at the Arsenal should, at the discretion of the Director of Artillery, as was the existing rule, be submitted to the Ordnance Committee. These recommendations were not carried out. It was considered that the transfer of all drawing and designing to a central office would weaken the responsibility of the superintendents in the designs of their own productions.

(*b*) Growth and Lay-out.

The story of the development of the Ordnance Factories is bound up with the question of the general policy of the Government in obtaining munitions of war. Just before 1859 England had relied very largely upon supplies from the Government factories. The experience of the Crimean War led to a change of policy, and from 1859 the system was adopted of obtaining munitions partly from the trade and partly from factories under direct Government control. Lord Morley's committee in 1887 favoured a very considerable reliance on the trade.

> "Not only does it stimulate inventors and manufacturers to vie with one another in producing the best possible articles, but it tends also to widen the area of production, so that in time of pressure . . . the requirements of the service would be more readily supplied."

They deprecated the large discretion allowed to individual superintendents in the matter of extensions, and advised that any further expansions should be jealously watched and controlled by the War Office.

The South African war proved the Ordnance Factories to be capable of the expansion required for a war of that magnitude, but the pressure was at times very great, and since the factories were then

called upon to meet the demands of the land service only, it was recognised that a greater expansive power must be provided to meet the requirements of a war involving both land and naval forces. The war had also brought to light the fact that considerably more time was necessary than had been anticipated for the armament firms to reach their full capacity, and that they were liable to fail entirely in the production of certain essential components, as happened in the case of fuses. It appeared, therefore, that both trade and Government factories needed fostering and the principal difficulty was to determine a fair distribution of work in peace time between the Ordnance Factories and the armament firms in order to create a certain reserve capacity in both, without involving impossibly uneconomical production. Before the South African War the general arrangement was to allocate orders equally between the two sources of supply, though to a certain extent allocation depended on comparative prices. After that war the proportion was changed, roughly a third being assigned to Woolwich and two-thirds to the trade, this division applying more particularly to gun manufacture and being less definite in the case of other stores.

A scheme put forward in 1900, included proposals for increasing the productive power of the Ordnance Factories at a cost estimated to exceed £1,000,000. This programme was referred to a committee presided over by Sir F. Mowatt, for consideration as to how far the trade could be relied on for expansion required in time of war. The committee expressed the opinion that the factories should be so organised as to be able materially to increase their ordinary output in times of national emergency, or in the event of temporary failure of deliveries from the trade, but stated their conviction that this reserve power could only exist so long as the work assigned to the factories was well within the capacity of its normal staff working the ordinary number of hours per week. It was therefore essential either that the ordinary demands on the factories should be reduced or that large additions should be made to the buildings, plant and staff. The committee finally pronounced in favour of the former alternative, at the same time recommending certain additions to plant and buildings which, though less comprehensive than those proposed, were yet considerable. These recommendations were adopted and carried out by the Secretary of State with the result that in 1907 the equipment of the Arsenal was considerably more effective than it had been before the South African war. It became the policy of the War Office to provide a capacity for rapid expansion at Woolwich to tide over the first stages of a war before the firms were in a position to reinforce their efforts. During the same period the staff at the Arsenal had been systematically reduced, with the result that in 1905 a large proportion of the machinery was standing idle and the cost of production at the Ordnance Factories was becoming very large. Another committee, under the chairmanship of Sir G. H. Murray, was then appointed to consider among other things whether Government production could be advantageously replaced by private enterprise, and if so to what extent and on what terms. This committee reported in March, 1907. They assumed that the ideal

would be that the Arsenal should not be allowed to expand beyond the minimum point of economical production, consistent with the power of rapid expansion, but they found that the principle of economical production was incompatible with that of rapid expansion, and that the power to expand was more important than economy. They obtained from the superintendents of the various factories figures giving approximately the greatest number of workmen who could be efficiently employed on the existing plant and the smallest nucleus establishment from which this maximum number could be reached without unduly hampering production. They held that the proper establishment of the factories lay at this minimum, and that work should be allocated to the factories sufficient to keep this number fully employed, all surplus requirements being made up by recourse to trade sources. It had been found that the former system of allocation led to inconvenient fluctuations in the work at Woolwich, where no organisation existed, as in the trade, for transferring employees to other work when the demand for munitions was small. It was admitted that special enquiry might be necessary to decide the exact figures for the minimum nucleus, and those below were suggested.

	Maximum.	*Minimum.*
Royal Laboratory	13,000 ..	3,500
Gun Factory	5,000 ..	2,000
Carriage Factory	3,700 ..	2,500
Royal Gunpowder Factory	1,500 ..	600
Royal Small Arms Factory	3,500 ..	2,000

The economic question of the effect upon the district of the discharges from Woolwich was becoming serious in 1907, and it became necessary to explore the possibilities of utilising the capacity at Woolwich for the production of stores other than munitions of war. Woolwich was equipped with machinery of a very varied and comprehensive nature, and it was suggested that other Government stores, such as barrack and hospital stores, camp equipment, accoutrements, harness and saddlery, should be manufactured there. It was, indeed, urged in some quarters that the Royal Arsenal should, in time of peace, be regarded as a great State manufacturing department, which should be utilised in meeting the requirements of all Government Departments, so far as its capacity allowed. Apart from the consideration that it was inadvisable that the Government should compete with trade, the contention of the Chief Superintendent that the *raison d'être* of the factories was that they should be prepared for sudden emergencies appeared to be unanswerable. The machinery of the Arsenal, though in itself applicable to general engineering, was arranged for a particular sequence of operations to produce a particular article, and if such machinery was diverted from its proper production, it might be impossible to retransfer it without loss of time, and serious danger to the country might ensue. Moreover, if work other than the manufacture of warlike stores was undertaken for other Departments it would have to be under the condition that immediately on the outbreak of war such work would have to be set aside, and this might be very inconvenient to the Departments concerned.

It seemed necessary to face the fact that to ensure the country against danger from sudden emergency, economy must take a second place, that in peace time a large proportion of the machinery of the Arsenal must stand idle waiting for the emergency to arise, and that a working staff must be retained adequate to control and instruct the additions to the army of workers which would be necessary to man the machines which, during peace time, were held in reserve. It was, however, suggested that the Navy might increase their orders upon the Arsenal for heavy gun mountings, but this idea was rejected by the Admiralty.

A committee appointed in 1909 to enquire into the organisation and resources of the factories advised that the conditions then obtaining were quite different from those of 1900, since the Army and Navy now had reserves of guns and stores sufficient to tide over the early stages of a war, while private factories had expanded to such an extent that each had a considerable reserve of plant to meet emergency orders. This seemed to justify a modification of the policy recommended in 1900. The committee's recommendations dealt chiefly with the reserves of machinery, the establishments having by that time been reduced to something nearly corresponding to the minimum. The expansion of the factories between 1897 and 1907 had been very great. The capital value of the buildings rose from £624,312 on 1 April, 1897, to £1,096,332 on 1 April, 1907, and this in spite of the fact that during the intervening ten years £405,426 had been written off the capital value of the buildings, which sum had been levied as depreciation and charged against the productions. Similarly, the capital value of the machinery had increased from £570,609 on 1 April, 1897, to £773,255 on 1 April, 1907, while £673,627 levied as depreciation had been written off the capital value. The committee regarded with suspicion the whole policy of preserving old machinery in view of emergency, or of building up a large reserve to that end. They pointed out that military requirements were constantly changing with the progress of mechanical invention, and that the only cases in which reserves were justified were those of special manufactures which could not be obtained from the trade and might be urgently required during the initial stages of a war. They held that much of the machinery held as a reserve was really surplus and should be sold or scrapped. As a result of this committee's recommendations a certain amount of surplus machinery was disposed of, the rate of depreciation on buildings was reduced from 5 per cent. to 3 per cent., and a maximum limit was fixed for annual expenditure on repairs. The proposal to fix a limit for annual expenditure on new buildings was not, however, adopted. The committee desired to fix a maximum limit to govern both the expenditure on new machinery and its repair and maintenance. The amount of money thus allocated, following upon the adoption of the report, was inadequate, and the expenditure on each machine had to form the subject of a separate request, with the result that on the outbreak of war the machinery generally was in a bad state of repair, unfit to stand the strain imposed by demands created by the war. The recommendations of this report had not

been fully acted upon by the outbreak of war, and some of the condemned machinery did valuable service throughout the war. The concentration of shops recommended by the committee effected little, the same shops in some cases having to be rebuilt on the same site after the outbreak of war.

The percentage of the total production of armaments produced at the Ordnance Factories showed a marked decrease between 1909 and 1913 in the case of every kind of store. The size of the nucleus establishment was perforce based upon the estimated requirements. It provided for a moderate expansion commensurate with the demands likely to be made. It was, accordingly, inadequate to meet the vast expansion actually required in August, 1914. The measure of this expansion may be realised from the fact that before the middle of September, the Ordnance Factories had done more work for the Navy than the Board of Admiralty had communicated to them as required for the first six months of a war in which all the land and sea forces of the Empire were engaged. The inconvenient lay-out of the factories was one of the most serious factors in hindering rapid expansion. The Arsenal had been built up by degrees for generations back. Some of the shops were very old, badly lighted and ill ventilated. The three factories had been originally kept distinct, but insufficient space had been allowed for their expansion within their own boundaries, and encroachment had been made by one upon another. An ideal factory would, no doubt, have had a single chemical laboratory, testing house, and gauge and tool factory, but Woolwich had many of them scattered throughout its area. The efficient siteing of new shops built during the war became difficult if not impossible, and the congestion, which increased as the war went on, made efficient and economical management more and more difficult. Similarly neither the site of the Royal Gunpowder Factory at Waltham nor that of the Royal Small Arms Factory at Enfield was adapted for any considerable extension.

Various legacies of the past had, in fact, placed the management of the Ordnance Factories at a serious disadvantage in meeting the heavy demands made upon them at the outbreak of war. The lay-out of all the factories prevented expansion on well-ordered lines, and the lay-out at Woolwich involved traffic congestion directly mobilisation began. Much of the machinery was known to be out of date and in a bad state of repair. The staff was not adequate for the efficient management of the factories when working at their maximum capacity, and insufficient provision had been made for a reserve of foremen. The exceptionally favourable conditions already promised to employees militated against economical production, and concessions made during the course of the war had a similar effect.[1] The established routine in regard to accounting was not the best suited to act as a check upon contractors' costs or for comparison with those of the new national factories.

As compared with the Ordnance Factories, the Royal Aircraft Factory at South Farnborough is a very modern establishment.

[1] See below, p. 14.

The factory developed from the sheds and workshops of the Balloon Factory built at South Farnborough in 1905. It was, therefore, free from many of the difficulties which beset the Ordnance Factories. Its layout was modern and convenient. On the outbreak of war a large proportion of the spares for the Royal Flying Corps was being supplied and stored by the factory; but arrangements had already been made to start at Pinehurst the Aeronautical Ordnance Department, a Military Stores Department which began in August, 1914, to take over from the factory the duty of holding stores for issue to the Royal Flying Corps, with the exception of special items such as instruments. Aircraft Inspection had been decentralised before the war. Detailed inspection took place at contractors' works, and though final erection and flight tests were at first carried out at Farnborough, this part of the work was also decentralised early in 1915. Thus no problems of traffic congestion arose there on account of the demands of different departments on the means of transport. From the outset Farnborough was under civilian management. The necessity for the military element in management did not arise in the case of aircraft supply, which was essentially a civilian occupation before the war, and the interests of the users were sufficiently safeguarded by the direct responsibility of the Director General of Military Aeronautics for the management of the factories.

III. Labour Conditions.

Since 1903 the close connection between education and efficiency in such an establishment as the Arsenal had been clearly recognised, and a great deal had been done, by reducing the hours of labour and providing access to technical information, in raising the general educational standard of the workmen. The managerial staff was formed into an upper and lower division, and the upper division was recruited by the annual appointment of three "supervisors" chosen by an examination which aimed at securing men of higher qualifications, preferably of the University type, who, after obtaining degrees, came to the Arsenal for workshop training. At the same time the education of the trade lads (premium apprentices) was systematised and improved and promotion made to depend considerably on good educational reports. A reference library and reading room properly equipped with modern technical literature were opened free to all employees.

Shortly before the outbreak of war the Chief Superintendent was ordered to cut down all staff to an absolute minimum, and the shop staff was reduced so low that it was barely possible to carry on even in peace time. A further rule necessitated the discharge of lads on reaching the age of 18, unless it was then certain that work would be available for them at the age of 21, and the substitution of men who would otherwise be discharged on reduction. Thus the Arsenal was forced to get rid of most of the young men they had been training, including half the trade lads, who were relied on for future foremen. One consequence was that men were engaged upon jobs which could have been done by boys or women. On the outbreak of war great difficulty was experienced in getting young men with the necessary

trade and technical training. Such men were in great demand in the armament firms, and the limited prospects of promotion at Woolwich sent the best men to the trade firms.

Labour regulations and conditions at Woolwich were quite different from those existing in any other factory in the kingdom. The rates of wages were based on London district rates, but the normal working hours were less. A large part of the work was done as piece work. Prices before the war had been based on small outputs, and it was found that when output increased, these rates were very high owing to the skill acquired by repetition; but an express understanding of many years' standing that rates should not be cut was solemnly ratified by the Minister of Munitions in 1915, and prevented any alteration of these rates except by altering the method of manufacture. The position of the Woolwich factories in regard to dilution was also unique. The use of female labour at the Arsenal had been stopped, as mentioned above, many years before the war. The prohibition remained in force until August, 1915. Dilution of skilled labour either by women or unskilled men was strenuously resisted by the skilled employees of the Arsenal, and was accompanied by great delay. An arrangement was made in February, 1916, between the management and the Amalgamated Society of Engineers whereby in each group of shops the skilled workmen chose representatives to consult with the manager as to the description of work on which skilled labour might temporarily be displaced by semi-skilled or unskilled labour, either male or female. This arrangement was to begin when all substitutes under the scheme for the dilution of skilled labour had been removed from the skilled work to which they had been advanced. The effect of this arrangement was greatly prejudiced by an undertaking given by the Chief Superintendent that, since the scarcity of skilled labour was the only reason adduced for its dilution, he would remove the unskilled men who had been taken on if skilled men could be brought in from outside sources. Great and fairly successful efforts were made by the Amalgamated Society of Engineers to fulfil this condition, with the result that dilution was seriously retarded, and skilled labour unjustifiably hoarded. Any skilled man set free in one factory could practically claim that room should be found for him in another where dilutees were working. The progress in dilution was specially disappointing in the Small Arms Ammunition Factories.[1] The other two Ordnance Factories, unhampered by the restrictions which existed at Woolwich, experienced less difficulty in diluting labour. The Royal Gunpowder Factory eventually employed almost as many women as men. The Royal Small Arms Factory was prevented from introducing a large proportion of inexperienced labour only by the special character of the work. The Royal Aircraft Factory, also unhampered by precedent, introduced female labour at an exceptionally early stage in the war.

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[1] The percentage of women employed on skilled work in Small Arms Ammunition Factories was as follows:—

	December, 1917.	*July*, 1918.
Messrs Kynoch	32%	29%
G.C.F. No. 1.	70	64
Woolwich	5	25

IV. Finance and Accounting.

Before the votes for the separate factories were amalgamated in 1888, the manufacturing accounts submitted by each factory were mere statistical statements which did not form the basis of any charges against army or navy funds. Account was kept of the wages of men employed, and of material directly consumed on an order. To this was added a proportion of indirect expenditure, the total indirect expenditure being levied as a percentage on direct labour charged against each order in the cost ledger of each department. These three items formed balance sheet No. 1, in the accounts of the manufacturing departments annually presented to Parliament. As, however, this balance sheet took no account of depreciation or of capital expenditure, it did not allow of fair comparison between the cost of articles manufactured by the Government, and of articles purchased from the trade, and a second form of account was evolved in 1864, called balance sheet No. 2, which included a charge to cover estimated depreciation of buildings and machinery and interest on invested and working capital, viz., depreciation on buildings 5 per cent., on machinery 10 per cent., and interest on invested capital $3\frac{1}{2}$ per cent., and on working capital (taken at one-fifth annual expenditure) $3\frac{1}{2}$ per cent. In the annual account the cost of each article was calculated both on No. 1 and No. 2 balance sheets.

Lord Morley's committee criticised the system of checking wages, which seemed too elaborate in view of the fact that it was impossible to apportion the indirect expenditure accurately between the different orders. They reported that it might be simplified with advantage, but suggested no definite change. This system was still in operation when the accounts of the factories were investigated by the experts who reported to Lord Randolph Churchill's Select Committee on Army Estimates in 1887-8. This report advised no change in the system, on the ground that it was simple and, at the same time, sufficiently accurate for the purpose of the Ordnance Factories as then circumstanced. In 1888, however, a change was effected in the method of Parliamentary provision, by the introduction of a vote for the Ordnance Factories as a whole, instead of a separate vote for each, and in 1890 the whole system of accounts was overhauled and centralised. By this means there were obtained uniformity of system, facility of preparation of Parliamentary accounts, economy of staff and control of expenditure. The system provided the Chief Superintendent of Ordnance Factories with a means of control over factory operations, while individual superintendents were allowed free access to the books, and were encouraged to make all possible use of it. The cost accounts of the factories, as far as labour was concerned, were based on the records made by a staff of "work-takers," who were the immediate subordinates of the officer in charge of the works accounts branch of the central office, not, as previously, subordinate to the superintendents of factories. By this system a reliable account was secured of work done and wages earned. Depreciation on machinery as well as cost of repairs, engine power and other current expenditure on plant was charged to indirect expenditure and ultimately distributed

as a percentage on the wages debited to orders in the cost ledgers, much in the same way as was the case in 1887. Exceptions to this rule were the Gun Factory, where it had long been recognised that the distribution of these charges as a uniform percentage on all classes of work would fail to give reliable costs for guns varying in weight from a few hundredweight to many tons, and the small arms factory then existing at Birmingham, which was divided into two branches for manufacture and repair of arms, the use of machinery being almost exclusively confined to the manufacturing branch. Special arrangements for meeting these cases had been introduced into the accounts, the work of the Gun Factory being divided into three classes, heavy, medium and light, and each class bearing an appropriate special percentage on materials and labour for "machinery charges," while at Birmingham the depreciation and other charges for machinery were practically all thrown upon the manufacturing orders. Such exceptions showed that the old simple method was no longer adequate to the altered conditions of manufacture, with the wide differences between the cost and working expenses of the different types of machinery, and the increased importance attaching to comparisons between factory and contract prices for similar stores.

Under this new system no charge for interest appeared in the accounts. As the actual cost of work done as shown in the public accounts was recovered from Army, Navy and India funds and credited to the account of the Ordnance Factory vote, it followed that if charges for interest were included in the cost, sums would be credited to the vote which had not been expended out of it, and the account would exhibit an annual surplus to the extent of such interest, contrary to its general intention. Since the main object of the cost accounts was to show the average price of each production for the financial year, separate accounts were not kept for different orders for the same production, so that no account could be closed until the end of the year. Since there was practically continuous manufacture of a large number of articles, it was impossible to obtain the actual cost without taking stock of articles in process of manufacture on each order. This was done at the end of each financial year, and the total expenditure on each order during the year reduced by the value of semi-manufactures at the end and increased by the value of semi-manufactures at the beginning, gave the cost of the net production on the order. Differences in cost of production occurring during the year which might have been of importance for purposes of supervision were not shown.

An enquiry was held into the system of accounting in 1901–02. Mr. H. F. Donaldson, then Chief Mechanical Engineer at Woolwich, a civil engineer of large experience, attached great value to a system of cost keeping which should be of assistance for administrative purposes. To attain this it would be necessary to handle each week's expenditure at once and make returns to those responsible within a week, so that immediate investigation could be made into any points requiring examination. This point had not been lost sight of when framing the system in 1890, and one of the first enquiries made when

the works accounts branch was constituted was as to the class and form of information with which the superintendents would desire to be furnished. This produced no suggestions, and the impression was conveyed that the superintendents did not care to have any such information. No further steps were taken, but the details were always obtainable if desired, and Mr. Donaldson thought that the value of semi-manufactures could be assessed weekly by work-takers and foremen, thus allowing for the production of weekly costs. The committee of inquiry was, however, mainly led by the report of Mr. Morland, an accountant, who, after making, at the committee's request, an independent comparison of the systems of accounts at the factories and at various armament firms, summed up the result of his examination as follows :—

> " Speaking generally, ... the system of cost accounting at Woolwich appears as well adapted to obtain the results required as that in use at any of the works visited. These results differ in character from those of commercial houses, owing to the absence of profit considerations and to the requirements of Parliamentary returns."

The committee, therefore, contented itself with recommending the adoption of the more accurate systems of allocating machinery charges, in common commercial use, by which the work done at each machine bears an appropriate charge estimated to cover depreciation on that machine, cost of its maintenance and the power it consumes. The committee considered the difficulty of the omission of charges for interest in obtaining comparisons between Ordnance Factory and contract prices, but came to the conclusion that such comparisons would not be facilitated, but rather the reverse, unless the sums included in the factory accounts for interest were calculated at a commercial rate of interest on a figure representing the commercial value of the factories. It did not appear that a Government rate of interest calculated on the capital value of the factories as shown in their books would fulfil this condition. Since it would always be necessary to make a considerable allowance in comparing factory prices with contract prices, for elements which enter into the one and not into the other, it appeared that no useful purpose would be served by incorporating charges for interest into the Ordnance Factory accounts. They reported that, subject to the adoption of the improved system of allocating machinery charges, the factory accounts were kept on sound principles and exhibited correctly the cost to the country of the production of the factories; but it was obvious that these prices could not be compared with the selling prices of contractors. Besides the element of net profit and interest on capital there were other elements of expenditure which contractors incurred, which did not exist or existed only in a minor degree in Government factories. Such were the cost of advertising and obtaining orders, the cost of protecting and working out inventions, insurance, provision for bad debts and slack times, and risk of loss through changes in type of warlike stores. The allowance to be made for these elements

was essentially speculative, so that no fixed percentage of difference between factory and trade prices could be laid down. It appeared that nothing was to be gained by departing from the basis of actual expenditure on which the Ordnance Factory cost prices then rested. The rates published in the *Priced Vocabulary of Stores* were in a large number of cases based on Ordnance Factory cost prices, and these rates were often wrongly supposed to represent full and fair selling prices, to the detriment of British manufacturers when dealing with customers in other countries. It was, therefore, recommended that words should be inserted, both in the Woolwich accounts and in the vocabularies, showing that there were certain trade charges not included in the Woolwich cost of production. As a result the following words were added: "prices shown in these accounts do not include rent of land, interest on capital or other trade charges, and risks not incurred in Government manufacture." When these words came to the notice of the Committee on Public Accounts they insisted on the further additions: "but on the other hand include charges for depreciation and upkeep of unused buildings and machinery, maintained with a view to expansion, and cost of care and custody of Imperial stock stores." These words seemed very essential in view of the fact that, in some instances, Woolwich had building and plant five times as large as were required for current work, maintained simply with a view to expansion in time of war.

From this time the possible use of costs in assisting administration appears to have been overlooked. A committee enquiring into the Royal Factories in 1907 were chiefly concerned by the number of qualifications and corrections necessary before comparisons could be made with other trade prices. They were doubtful whether the voluminous details contained in the accounts were worth the trouble and expense incurred in their production, and thought the publication of detailed prices in their existing form undesirable.

Parliamentary action thus tended to militate against any revision of the existing system of costing, which remained unaltered until the outbreak of war. It was the practice, however, to extract and furnish to the managers periodical statistics of shop non-production and certain other classes of indirect expenditure within their control.

After the outbreak of war expansion was the primary consideration; the staff of the cost accounting branch was depleted in order to strengthen the far more vital stores and wages branches and the Pay Office. Ascertaining costs became a secondary consideration, and when at the end of the financial year it was found impossible to close for stocktaking, the whole basis of the system gave way and the account could not be built up in the correct form. The question was referred to the Treasury, who intimated that all that they wanted during the progress of the war was an interim statement of expenditure with an approximate division into charges against the Army, the Navy, India and the various colonies served, but that they expected that a complete stock should be taken at the close of the financial year succeeding the termination of the war, and one complete account produced showing the actual cost of production of all the articles

manufactured during the war. In pursuance of this ruling the Woolwich accounts section booked expenditure currently against the several orders, and by estimating could arrive at the approximate cost, but owing to the delay in obtaining prices of materials, accurate costing was out of the question. Various information was, however, supplied to the superintendents at their request, during the war, such as weekly labour costs, machinery rates, day work and tool percentages, and non-production percentage, or the estimated cost of any particular article periodically so that the variation of price could be watched. Any periodic estimate of prices of all articles was out of the question on account of the expense and the inadequacy of the staff. On costs and non-production charges were, however, watched separately and records were sent to the factories. The weekly report of the work-takers also furnished the Chief Superintendent with a means of detecting any abnormal prices or unusual development of costs in the factories. The Controller of Small Arms Ammunition Factories watched efficiency indirectly by records obtained in the shops, relating to output, machine efficiency, stores consumption, tool consumption and numbers employed. Similarly the Controller of the Filling Factory watched efficiency by checking the quantities of material used with that estimated for, by watching output and by watching rejections and tool consumption. Ultimately, however, the preparation of a detailed production account for the whole period of the war was abandoned on the ground that the information would be of little use for comparison with pre-war rates or future peace-time costs.

Weekly progress returns were instituted at the Factories in April, 1916. The statistical records of output posted in the shops aroused great interest among the men and were believed to be the cause of a definite improvement in efficiency, not only on account of their effect on the men, but because they enabled the management to detect at once the cause of any drop in output.

At about this time (January, 1916) the Superintendent of Waltham and Enfield expressed a desire for the transfer of the accounts of his factories from the central office at Woolwich to his own office, in order that he might extract costs. He was, however, discouraged by the Ministry (E.M. 4.) on the ground that it was a mistake to undertake any complication or increase of work at a time of such pressure, when all information required could be reasonably well obtained by existing machinery, and that the matter was not one of urgent practical necessity in connection with output during such abnormal times. At a later date, Mr. Eric Geddes, in enquiring into the organisation of the factories as it stood when the Ministry assumed control, recommended that in view of the temporary nature of Ministry control, the costing system and accounts should not be disturbed. It must also be remembered that during the war considerable fluctuations in current costs would have excited no particular remark, since "rush" jobs entailing overtime and night work were of common occurrence.

The evolution of a system of costing over short periods, giving comparative statistical information to the management, and the establishment of such systems in the new national factories gave rise to

a demand for similar costing figures from Woolwich for purposes of comparison. At the end of 1917 the question was discussed within the Ministry of the desirability of reorganising the system at Woolwich in order to obtain results comparable with Ministry costs. Two experienced accountants by whom the subject was investigated were unanimous in thinking that the advantages of modernising the system would not compensate for the risks of temporary disorganisation and reduced production that would almost certainly have to be faced. The existing system could have been adapted to provide monthly costs of production had it been possible to take stock in the shops at the end of each month, but it was clearly inadvisable to place on the foremen or worktakers in war time such an additional burden of work, and the matter was dropped. The opinion of one of the accountants may here be quoted :—

> " I should like to express the view that under war conditions our principal aim should be to do nothing that will hinder methods that already work satisfactorily and also to avoid the pitfall—not uncommon to professional accountants—of allowing one's desire for ideal systems of safeguard and control to obscure the vital need for simplicity co-existent with a high standard of efficient production."

In the summer of 1918, however, the manufacture of munitions had developed to such an extent that the consideration of questions of economy and efficiency of production became possible and the absence of an adequate current costing system at Woolwich became the subject of much adverse criticism. On the one hand, the Ministry was anxious to obtain the costs of manufacture at Woolwich along lines exactly similar to those adopted in the new national factories in order to judge of economy in allocating capacity, and to check contractors' prices. On the other, the management of the Ordnance Factories, even had it not been fully occupied in producing the munitions so urgently required, was tied by past legislation to a system which differed in form from that established by the Ministry of Munitions, and could only be changed by the authority of the Treasury with the concurrence of the Auditor General and Public Accounts Committee. Nor did they, at that time, conceive it to be possible to engraft the Ministry's system upon the existing method of accounting without seriously increasing expense. Some considerable time after the conclusion of hostilities steps were, however, taken towards introducing a system of cost accounting, which, by the use of up-to-date methods of calculation, neither increased establishment expenses nor interfered with the accounts prepared for the Public Accounts Committee.

Both the historical development and the functions of the Ordnance Factories tended to increase the costs of production and to render difficult any comparison of costs between them and those of other armament producers. Economy was not consistent with the peace-time conditions which entailed the employment of highly skilled men

in comparatively unskilled work, and the upkeep of a large amount of non-productive machinery, all of which were imposed upon the factories by their character as a war reserve. These factors tended also to hinder the subsidiary function of the factories as a check on costs of production; although many prices, and particularly those of rifles and small arms ammunition, had been regulated by the Ordnance Factories' costs right up to the outbreak of war. Even before 1900, when the supreme importance of the factories as a war reserve became fully recognised, Woolwich costs were of doubtful utility for comparison with the prices charged by the trade on account of the differences in the bases on which they were calculated; after that time comparison became still more difficult. As explained above, Woolwich costs were in 1886 produced in two forms with a view to affording figures comparable with trade results, but successive committees pointed out the impracticability of comparison with trade costs. By 1909 high charges for certain productions of the Ordnance Factories became the subject of investigation by a committee. They appeared to be due, amongst other causes, to excessive capital and current expenditure caused by the provision of adequate war reserves, high rate of depreciation and heavy charges for maintenance of buildings and machinery. The difficulty of effecting reductions in the upper grades of the establishment, commensurate with the very considerable decrease in output and direct labour, also had a very distinct effect in increasing costs. The committee found that the factory superintendents were not responsible for the expenditure on maintenance of buildings, this being controlled by the Superintendent of Building Works, but that they had direct control over the expenditure on maintenance of machinery, subject to the approval of the Chief Superintendent for services over £50. They thought this system tended to the repairing or replacing of machinery, without adequate consideration of the question as to which course was really the most desirable from the point of view of economic production. There was reason to believe that the primary consideration with the factory superintendents was to secure efficient workshops and to reduce the amount expended on labour, while the question of keeping down the actual cost of their productions tended to become a secondary consideration. This may have been an outcome of the partial centralisation which removed the accounts from the responsibility of the superintendents, while leaving them considerable independence in other directions, a tendency which had been pointed out in 1902.

The site of Woolwich, at such a distance from the coal producing areas, and its bad layout also tended to increase costs. The wide separation of certain units which should have been closely associated led to a large amount of haulage of components between the various shops, and intensified the congestion already existing owing to the defective internal railway communication. The shops were in many cases overcrowded, due to war emergency installation of extra machinery without time being available to reconstruct the internal and external shop communication. The distance between the shops led to the multiplication of tool shops. All these conditions affected efficiency

and increased costs. At the end of the war it was stated that in the Royal Gun Factory, the only shops in which economical production was possible were the new gun machine shop, the new treating and annealing shops and the two press shops. There was a considerable amount of good new machinery in the other shops, but this had been placed in the available floor space between existing machines and the layout was unsatisfactory. The obsolete machinery of pre-war times which was still in use, was uneconomical in output and wasteful in power. In the Carriage Department the main shop was hopelessly congested, and no good means existed of handling materials and jobs to and from the railway. The sight-shop also was old-fashioned and congested. Similarly, the gradual growth of the Royal Gunpowder Factory along a narrow strip of land increased the haulage of materials from unit to unit, and thus rendered the position of the factory, as a standard of economical production, quite useless.

One of the principal factors in raising Woolwich costs of production and rendering difficult any comparison with trade prices was the multifarious nature of the work. The effects are almost impossible to gauge, but even in 1902 the jobbing work of all sorts, which was a feature of Woolwich, was recognised as differentiating it, as regards economical production, from an ordinary armament firm conducted on commercial principles. Most factories had a fairly straight run of work which could be arranged in the best possible way for production, but Woolwich programmes were subject to constant changes, and apart from the ensuing disorganisation the necessary alteration in layout of machinery accounted for considerable expenditure. A building put up for a certain purpose might, when converted to some other manufacture, need considerable alteration, as happened in the case of buildings laid out for filling Q.F. ammunition, which were afterwards used for filling fuses. The preparation of shops for new classes of work sometimes involved complete cleaning down or rearrangement of plant as, for instance, when a change was made to black powder filling, from the filling of phosphorus smoke containers into 18-pdr. shell. The costs at the filling factories were very much increased by the constant change of programme and great variety of work, the weekly programme frequently containing 300 separate items, while, as no other factories worked under similar conditions, fair comparison was impossible.

The cost of all the experimental work done in the Ordnance Factories was charged to production, while it also had an effect in increasing cost by interrupting supply work. The same factor operated at Farnborough, a machine being designed and drawings made to govern the production of some thousands of machines while the whole cost was charged to the few machines actually built at Farnborough.

Small arms ammunition manufacture at Woolwich was particularly affected by a combination of these factors increasing cost, though owing to the repetitive nature of the work it was often regarded as providing a suitable test for Woolwich prices compared with those of

other producers. The rolling mills were exceptionally expensive to run, owing to the fact that the shop had been originally built as a store for horseshoes, and was broken up by the iron pillars of the roof. There was no overhead crane and the relative positions of the annealing furnaces and mills were very awkward. In consequence the handling of material was very great and the labour required, though not of high skill, was of physically high standard, and therefore expensive. In the work of drawing and stamping, boys had been replaced by women at higher rates. Girl labour would have been preferable but was inadmissible on account of the night shift. Tool setting was, for the reasons explained above,[1] done by skilled men or by women at skilled rates, though all such work was done in the Birmingham area by semi-skilled labour. In one of the shops, inspection work which could well have been performed by young girls, was done by disabled men at men's rates. The shops in this group were so remote from each other that each had to have its own tool shop, and traffic between them was very wasteful. The kinds of work in progress at these shops were very numerous, forty different types at times being dealt with. The orders were frequently very sudden and often very small. Woolwich was also handicapped in this respect by the pre-war policy of excluding female labour and paying high piecework prices, a policy which could not be altered without breaking Government pledges. Overtime allowances at Woolwich were exceptionally large, while at the National Cartridge Factories and at the largest firms these allowances were smaller than those usually accepted in the engineering trade. The heavy oncost due to schemes of pensions and gratuities, hospital and medical attendance, etc., all of which were part of the factory system, tended to increase the cost of production, although in some instances an apparently uneconomical practice ultimately resulted in a gain to the Exchequer. Thus, for instance, the practice of giving prospective gratuities and current holidays with pay was counterbalanced by a reduction of 1*s.* in the £ below the district rates, which governed overtime as well, and converted an apparent loss into a distinct gain, when the men concerned were working 84 hours per week.

The position at Woolwich throughout the war has been aptly summarised as follows :—

> "The work Woolwich has undertaken has been largely of a character too unpopular for the private manufacturer to consider, or of such an experimental character as to preclude any opportunity for economical production being given to the management . . . . It is clear that the orders which Woolwich has executed have been nearly always in the nature of either experimental or panic demands, the essence of these contracts being not economical production but to bring the experiments to quick finality and speedy delivery of the goods to the fighting line, regardless of cost."

[1] See above, p. 14.

V. Achievements during the War.

(*a*) PRODUCTION.

Immediately on the declaration of war, expansion took place at all the Royal Ordnance Factories by employing additional staff to work the shops to their full capacity. Night shifts and overtime work were introduced into all departments. It was soon found that this expansion was insufficient to meet the heavy demands made upon the factories, and that actual extension to both plant and buildings would also be required.

The actual area of extensions which took place in the Woolwich Factories during the war in the several departments was 1,520,572 sq. ft. in the Royal Laboratory, 588,342 sq. ft. in the Carriage Department and 273,302 in the Royal Gun Factory, the total for the whole Arsenal being 3,433,609 sq. ft. The extensions to Waltham Abbey were strictly limited by local conditions, the unfavourable layout, due to the piecemeal growth of the factory, and the obvious risks of concentrating dangerous operations in a district peculiarly subject to air-raids. Certain extensions were made to the cordite plant during 1914 and 1915; but the construction of the enormous state factory at Gretna thereafter lessened the need for expanding the cordite plant. Tetryl plant was increased in the autumn of 1915, but this manufacture was subject to peculiar danger. Much of the purification plant was destroyed by fire, and ultimately the output from the Ordnance Factory was entirely replaced by the new plant at Queensferry.

Considerable extensions were made at Enfield, and included new shops of practically every kind required for small arms manufacture; but here again local conditions strictly limited expansion, and projects for doubling the capacity of the factory were abandoned on this score.

Of the many activities of the Royal Factories during the war, it is possible to notice only a few of the most important which illustrate their success or failure in fulfilling their functions as a war reserve. As regards the Woolwich factories, the work of the filling factories between August, 1914, and December, 1915, is of outstanding importance. The filling of the entire requirement of high explosive shell for the land service and from 40 to 50 per cent. of the naval requirements was carried out at Woolwich when war broke out. The remainder of the filling of naval shells was done at the Naval Ordnance Depots, but these soon became so much occupied with repair work that little filling could be done there, and the Admiralty became more and more dependent on Woolwich capacity. Woolwich also undertook the filling, assembling and finishing of large quantities of empty shell produced by the trade, and did the greater proportion of the filling of components and fuses, though a few fuses and minor components required by the land service were filled by the trade. At the beginning of the war picric acid was the standard high explosive for all classes of shell, and reliance was placed on Woolwich alone for melt filling with this explosive. When T.N.T. was adopted

in October, 1914, as a substitute for lyddite in the larger shells it was possible to adapt the melt plant to T.N.T. filling, and Woolwich continued to do all high explosive filling until the following spring.

Another very valuable aspect of Woolwich work during the war was the production of many special or experimental stores required in small quantities only. Of particular importance was the work of the Royal Laboratory in producing special small arm ammunition. The supply and design of this ammunition was one of the most difficult problems of the war, and it was largely due to the untiring efforts of the Royal Laboratory that the technical difficulties were overcome and supplies placed on a satisfactory footing. In the early days of the war Woolwich supplied the only available tracer and armour piercing ammunition. The early types proved unsuited to meet the demands of the services, and much research, the greater part of which was carried out at the Royal Laboratory, was necessary before satisfactory types were evolved. Owing to the numerous manufacturing difficulties which were encountered in producing these stores, supplies from trade sources were unreliable, and Woolwich had to undertake the production of all types, the Royal Laboratory output on many occasions saving the situation when trade deliveries failed.

For certain stores the Ordnance Factories were the only source of supply for the first months of the war. The only grenade in use in the Army at the outbreak of war was the Royal Laboratory percussion grenade which was manufactured solely at the Laboratory until June, 1915, and even after that time Woolwich still remained the sole maker and filler of the detonator.

Though before the war manufacturers of warlike stores had supplied their own shop gauges, Woolwich alone manufactured inspection gauges. After the outbreak of war, though output from the Ordnance Factories increased from 200 to 300 per cent., Woolwich was unable to produce fast enough to meet the demand, and by the middle of 1915 the requirement for these gauges had increased far beyond the capacity of Woolwich to supply them. Contracts were being very widely placed by Chief Inspector, Woolwich, before the formation of the Gauge Department of the Ministry. After gauge supply had been organised by this department, Woolwich still continued to supply all its own gauges and a considerable proportion of those required by the department.

Though in August, 1914, the capacity of the Ordnance Factories included the production of nearly every warlike store then recognised, there was one exception which led to somewhat serious results. For supplies of picric acid before the war entire reliance was placed on the trade. On the outbreak of war the services were depending on picric acid as the bursting charge for all high explosive shell. A reserve of 150,000 lbs. was held at the Ordnance Factories on behalf of the Navy, but there was no special stock kept to fill the small requirements of the Army. It had been assumed that large quantities would be forthcoming from the trade on very short notice, but immediately on

the outbreak of war it was found that the trade was incapable of carrying out the part assigned to it. By October, 1914, the increased use of high explosive made it necessary to increase the supply by erecting national plant, but the work of the Ordnance Factories was already so congested that the Chief Superintendent was unwilling to undertake the organisation of high explosive manufacture, and the work was assigned in January, 1915, to a special section of the Directorate of Artillery, which later became the Explosive Supply Department. It thus came about that neither picric acid nor T.N.T., which began to displace picric acid as the standard high explosive at about this time, were ever manufactured at Waltham Abbey, though plant for the production of T.N.T. which had been set up, on a semi-industrial scale, in the Research Department, Woolwich, for investigating manufacturing processes in October, 1914, was temporarily regarded as an important source of supply. For similar reasons the manufacture of the new ammonium nitrate mixtures was not undertaken at the Royal Gunpowder Factory. In addition to the actual shortage in supply caused by reliance on the trade for high explosives, delay in starting up new sources of supply was occasioned because the new supply department had no source of exact and practical knowledge as to manufacture.

Some of the new weapons evolved during the war were never manufactured at Woolwich owing to the fact that they could be more conveniently produced elsewhere. Such were tanks, mechanical transport and certain naval stores, while the assembling of chemical shell was only undertaken for a very short period.

A somewhat similar state of affairs to that produced by the failure to manufacture picric acid at the Ordnance Factories before the war was brought about in aircraft supply by the policy of depending on the trade for supplies of benzyl alcohol, an important ingredient of dope. It was the practice of the Aircraft Factory to purchase it in the market as a raw material, and it was not until war broke out that it was discovered that it was a German monopoly. Its preparation was immediately undertaken at Farnborough, but it was some time before manufacture on a large scale became possible.

Throughout the war both Woolwich and Farnborough were called upon to act as a balancing capacity to make good failures in deliveries from other sources, or to meet sudden urgent demands from the front. During the first two years of the war this adjusting process was a very imperative and frequent one at Woolwich, the Chief Superintendent being advised direct from the War Office almost daily as to which articles to push forward and which to defer to make way for them. Woolwich was depended on equally by the Ministry of Munitions in this way, and there seems to have been complete unanimity as to the efficient manner in which the Ordnance Factories responded to demands thus made upon them. In meeting these " rush " demands Woolwich was greatly assisted by its proximity to the Inspection Department, enabling it to obtain drawings at a few minutes' notice.

Notable instances occurred in the autumn of 1917, when the filling and assembling shops worked continuously throughout enemy air raids, to assemble anti-aircraft ammunition required for the barrage fire for the defence of London, and again in March, 1918, when the same was done, to meet the demands of the Army for ammunition during the German offensive.

There can be no doubt that Woolwich fulfilled its promises of production in a way that no other supplier did, and when it is remembered that normal output of ammunition was constantly disturbed by urgent demands for output of special stores, and that the attention of the expert staff was largely engrossed in the development of design, the steady output of small arms ammunition given by Woolwich tends to negative the charge of bad organisation. On the other hand, labour costs at Woolwich were undoubtedly high, owing, largely, to circumstances over which the management had no control, and it is remarkable that one of the features most criticised, viz., the adoption of a normal 48-hour week was afterwards generally accepted throughout the country.

The Ordnance Factories were sometimes accused of undue deliberation in accepting new processes. The fact that Woolwich was an adjusting factory, liable to constant changes of programme without notice, made some proposals which were generally accepted as improvements, inapplicable to it. Such developments could only be justified and carried out in works where it was a condition that an unlimited demand could be assured over a long period for an article or type. These conditions never obtained at Woolwich, either in peace or war. On the other hand, Woolwich did in many instances adopt labour-saving devices and improved processes from other factories, but the general practice was to abstain from changes in process or machinery without adequate trial, and this position was justified in many cases by failure of machines or processes which gave early promise of success, as in the case of a machine for filling primers used at Cardonald. There can be little doubt, however, that munition supply would have been benefited by a greater measure of freedom in exchange of views between the Ordnance Factories and the newly established national factories.

(*b*) Design and Experiment.

Owing to war conditions the demand both for supply and design work at Woolwich increased very greatly during the early years of the war, and there was a tendency for supply to take precedence over experimental work. At the beginning of 1916 it was suggested by General Bland, the Chairman of the Ordnance Committee, that in order to meet this difficulty the staff connected with experimental work at the factories should be entirely separated from the staff connected with output, and from all other routine duties in the Arsenal. A Superintendent of Design was appointed to watch the

interests of design and experimental work as opposed to output and supply. He took over all the duties of the Chief Superintendent with regard to design, and was an *ex-officio* member of the Ordnance Committee. He had a staff of designing officers and had control of the three departmental drawing offices, and was responsible for the manufacture of experimental stores. The suggestion was made that the Superintendent of Design should be in London with his staff, but on due consideration it was decided that it was most essential that the drawing offices should be in close touch with manufacture so that officers responsible for the drawings could see the original stores being made and alter design, if necessary, to facilitate workmanship during the initial manufacture of trial stores.

The advisability of trying out all stores thoroughly and placing them on a manufacturing basis before ordering from the trade was a well-defined policy at Woolwich, for it was held that initial delays which might occur through the necessity for careful tests, were justified by the ultimate economy in eliminating alterations during manufacture. The exigencies of war-time production not infrequently prevented strict adherence to this policy, but it was adopted where practicable and sometimes drew upon the Arsenal accusations of an obstructionist tendency with regard to designs initiated elsewhere. Instances of this policy occur in the development of the supply of trench warfare stores. From October, 1914, to June, 1915, the Ordnance Factory and Messrs. Vickers were the only producers of trench mortars. Manufacture of the 2-in. trench mortar, which had been designed at Woolwich, was confined to the Ordnance Factory on account of defects in design which were only gradually overcome. For the same reason the 4-in. trench mortar ammunition was made at the Royal Laboratory alone until April, 1916. The congestion at Woolwich during the first six months of 1915, led the Chief Superintendent to place sub-contracts for trench warfare weapons with the trade and as these weapons became simplified, more and more reliance was placed on the trade, until by the end of 1916 all work on mortars and their ammunition had been withdrawn from Woolwich. On the same principle, the filling of smoke and star shell was undertaken at Woolwich, on the ground that it was research work and needed watching. In designing aircraft for Land Service this principle was equally well recognised, but the difficulties of carrying it out were much greater than in the case of most of the stores dealt with by the Ordnance Factories, owing to the rapidly changing requirements of performance, and the comparatively long period of trial required for aeroplanes and aero-engines.

Insufficient allowance had been made in pre-war arrangements for the expansion required in the factory drawing offices at Woolwich on the outbreak of war. There was a sudden large demand for drawings to guide the trade both for naval and military orders. The Admiralty was entirely dependent on Woolwich for drawings, and the drawing offices soon became congested, the difficulty being increased by the number of alterations required in the drawings, and by the need for

subdividing drawings in order to spread manufacture. Amendments had to be agreed between the drawing offices and the Inspection Department who sealed the drawings, and this often led to considerable delay.

Administratively the drawing offices still remained under the superintendents of the different factories, after the appointment of a Superintendent of Design, and in the Gun Factory the superintendent still initiated gun design, in which matters he had considerable experience. Design in the Carriage Department was undertaken by three of his assistants, all military officers, one of whom was a specialist in gun mountings. In the Royal Laboratory drawing office the Superintendent of Design placed a number of officers, and the Superintendent of the Royal Laboratory, whose administrative work was particularly heavy, had no responsibility for design.

As the war progressed the design of munitions became, to a certain extent, decentralised. The dependence of the Ordnance Board during the first eighteen months of the war upon Woolwich experience was very great, but the formation within the Ministry of Munitions of branches such as the Trench Warfare Research and Chemical Research Departments provided other expert advisers for the new Ordnance Committee, and decreased the responsibility of the Chief Superintendent for new designs. Already in May, 1915, the delay in obtaining drawings had caused the Admiralty to set up a drawing office at headquarters, which, while originally intended to deal with drawings, was gradually extended to include much design work of a simple character. More complicated designs and matters involving prolonged research were still referred to the Chief Superintendent and the Ordnance Committee. After the establishment of the national factories, a certain amount of research work was carried out by them. As the war progressed, a gradual division of design work took place between the Ordnance Factories and the trade. The Royal Laboratory retained its importance in shell and fuse design, owing to long experience. Experimental work on fuses was continuous: a shop specially maintained for this work was always fully occupied.

It was the province of the Director General of Munitions Design to consult the supply departments with a view to checking economy and availability of material, the object of the Superintendent of Design and the Ordnance Committee being rather to obtain the best store irrespective of cost. It seems doubtful whether the question of cost was given due consideration in Woolwich design. It has been stated that when commercial firms started making munitions they were much hampered by the unpractical nature of certain of the designs which came from the armament firms and from the Ordnance Factories. For instance, the designs would show square corners instead of corners that could be dealt with without any very conspicuous machining process. In the early days of the war some fuses, designed at Woolwich, had $14\frac{1}{2}$ in. thread and were of bastard sizes, no jigs or gauges being available for their manufacture. In

this relation it should be noted that the very circumstances which made the Ordnance Factories the home of experimental manufacture, prevented any great importance from being assigned to ease of repetition work, since the factories were specially equipped to deal with small scale production to a fluid design.

One branch of design remained peculiar to Woolwich throughout the war, namely, the execution of repairs involving design work. The utility of Woolwich in this respect was very great. The Gun Factory was regarded as an expert adviser in these matters both for the Army and Navy, and this special branch of the work accounted for a large proportion of the work of the shops.

Design at the Royal Aircraft Factory, Farnborough, followed a very similar course to that at the Royal Ordnance Factories. For the first year of the war the Director of Military Aeronautics was almost entirely dependent for technical advice on the staff at Farnborough. The jealousy aroused in the trade on account of the government factory's having so considerable a voice in the approval of design led to the establishment of an independent design branch at headquarters to correspond roughly to the Ordnance Board in ordnance supply, and thus remove any suspicion that the government factory unduly influenced approval of design. The growing experience of the aircraft industry led at the end of 1915 to a division of responsibility for actual design of aircraft between the trade and the Royal Aircraft Factory, and left the latter more free to devote itself to special work involving more patient and prolonged experiment than could be entrusted to any of the firms.

In fulfilling its rôle as a source of experience Woolwich was seriously handicapped by previous political action. This aspect of the Ordnance Factories had not been entirely overlooked before the war, but no special provision had been made for carrying out the duties connected with it. The necessity for maintaining a staff in excess of the actual requirements of the minimum cadre had been clearly recognised in 1907, but the need for a certain amount of missionary work among the firms on the part of Woolwich foremen and inspectors does not appear to have been foreseen, probably for the reason that the recruiting of new firms into armament production was not at that time anticipated. After 1909 the staff was reduced to such a degree as to be unable to meet the needs of the Ordnance Factories themselves when expansion took place.

During the winter of 1914–15, when the question of extending the area of supply was becoming increasingly urgent, it was arranged that representatives of firms undertaking the manufacture of munitions were to be allowed to visit the shops, inspect the whole processes of manufacture and receive whatever information and advice they needed. This threw a great burden on the already overworked managers and foremen, and it was decided by the Chief Superintendent that these visitors should be passed through the Mechanical

Engineering Department, where a small staff was trained for the special purpose of taking visitors round the factory. Instruction sheets were also drawn up and printed, giving details of the various operations in the manufacture of 13 and 18 pdr. shrapnel and other shell and their cartridge cases. A more or less regularised procedure was then adopted under which firms were invited to send representatives to Woolwich to see actual operations, but the numbers were necessarily limited. In this way from May, 1915, to January, 1917, upwards of 1,500 visitors, representing many hundreds of firms, visited the Mechanical Engineering Department alone, while many others interested in guns and carriages went to the Gun and Carriage Department direct. While the National Filling and Projectile Factories were being established throughout the country, Woolwich did good work in instructing the managing staff in their new duties. In addition the Ordnance College at Woolwich was thrown open for their use.

The Royal Aircraft Factory was never relied upon for production in the way that the Ordnance Factories were. It was essentially a centre of research and experiment, and was not designed as a reserve of productive capacity to supply the first urgent requirements of war. Manufacture was carried only so far as to ensure that the difficulties of production had been overcome, and the factory was thus enabled to fulfil its rôle as headquarters of instruction and research far more easily than were the Ordnance Factories. Drawings to guide the manufacturer of machines of factory design were quickly forthcoming after the outbreak of war, and the inspecting staff, which was, however, independent of the factory, was already fully organised to give instruction to new contractors, though difficulty was found in increasing the staff adequately as the number of firms undertaking aircraft supply increased.

(*c*) REVIEW OF OUTPUT.

The best criterion of the achievements of the Ordnance Factories is perhaps to be found in a reference to the figures of their production during the war. The output of the Arsenal was large in quantity, varied in character and reliable in quality, and the striking increases in the outputs of the various stores between 1914 and 1916 are the best witness as to the manner in which the factories fulfilled the purposes for which they were designed before the war. Whilst the miscellaneous production of the factories was among the most noteworthy of their achievements, it is the most difficult to estimate by reason of its sheer diversity. Over 10,000,000 items of various kinds were produced by the Gun and Carriage Factories. The secondary stores made by the Royal Laboratory ranged from classes of which the output was less than one hundred to the various kinds of shell components, which amounted in the aggregate to nearly 31,000,000. In addition, the sum of the miscellaneous articles supplied by the

Royal Laboratory was nearly 300,000,000. The bulk output of the Ordnance Factories during the war is shown in the following table :—

BULK OUTPUT FROM THE ORDNANCE FACTORIES, AUGUST, 1914—DECEMBER, 1918.

	1914. Aug.—Dec.	1915.	1916.	1917.	1918.	Total.
Woolwich.						
Guns :—						
New	126	694	931	937	1,638	4,326
Repaired	387	921	1,137	2,079	910	5,434
Gun Carriages :—						
New	90	506	482	408	679	2,165
Repaired	158	242	152	319	346	1,217
Gun Ammunition :—						
Empty	124,600	1,219,000	1,749,600	1,536,900	1,217,300	5,847,400
Filled	233,200	2,094,400	6,810,100	6,181,400	4,591,200	19,910,300
Cartridges :—						
Filled[1], [2]	942,500	5,092,100	10,553,300	16,238,000	13,295,300	46,121,200
Fuses :—						
Empty	—	—	—	331,300	3,037,000	3,368,200
Filled[1]	219,000	2,046,100	18,231,100	22,939,500	15,815,600	59,251,400
Trench Mortars :—						
New	12	496	391	—	—	899
Repaired	—	58	4	6	—	68
Mortar Bombs ..	545	189,515	156,652	5,388	—	352,100
Small Arms Ammunition	30,223,500	286,623,400	502,394,100	531,947,200	367,625,000	1,718,813,228
Enfield.						
Rifles	63,107	253,545	413,424	618,073	659,423	2,007,572
Machine Guns	13	38	307	308	—	666
Farnborough.						
Aeroplanes	—[3]	31	155	163	133	482
Aero-Engines, Repaired	—[3]	203	559	599	949	2,310
Waltham Abbey.	*Short Tons.*	*Short Tons.*	*Short Tons.*	*Short Tons.*	*Short Tons.*	*Short Tons.*
Cordite	1,260	3,654	4,875	9,459	5,877	25,125

[1] Includes some of Woolwich Manufacture. [2] *i.e.*, complete rounds of ammunition assembled and filled. [3] No figures available.

CHAPTER II.

THE ESTABLISHMENT OF EMERGENCY FACTORIES.

I. Introductory.

Before the end of the war the country was covered by a network of state-directed factories which had come into existence with mushroom-like growth in the short space of a few years. Among these 200 industrial plants,[1] on which a capital of over £60,000,000 had been laid out, there were many privately established works which had been taken over by the Government and converted to national use under compulsory powers or by agreement. But the largest and most important individual enterprises were newly created, and had involved the erection and development of vast hives of industry on land previously unbuilt upon, the establishment of industrial dwellings, the laying out of streets and townships and the provision of all the necessary services incidental to the life of populous centres.

This sudden development sprang from a single motive—the need for fighting material. The demand for munitions had to be met at whatever sacrifice, and, like other war demands, the need grew more urgent as the range of effort widened and intensified. In particular it was the expenditure of artillery ammunition upon the Western battle-front, which assuming proportions never previously conceived, was not only the first to outgrow the capacity of existing sources of supply, but throughout the course of the war made the greatest drain on the powers of national mass production.

When war broke out the War Office looked to the Ordnance Factories in Woolwich Arsenal to carry the burden of ammunition supply, assisted by the resources of the long-established armament contractors who were familiar with work of this character. These firms in fact supplied 75 per cent. of the empty projectiles produced during the last quarter of 1914 ; but the loading and completion of these shells at this time fell almost exclusively upon the Royal Laboratory at Woolwich Arsenal. The first line of development to be pursued was the obvious one of encouraging in every way the expansion of the experienced armament works of the principal trade contractors, and the widest utilisation of their technical and specialised knowledge through sub-contract. They were urged to accept orders far in excess of their existing capacity in the hope that by sub-letting the simpler parts of the work and supervising the work of less experienced firms the immediate output would be multiplied, and at the same time the number of competent contractors would steadily widen as knowledge was diffused and experience was gained. Overseas

[1] A list of factories administered by the Ministry of Munitions, showing the order of their establishment as national factories, will be found in Vol. VIII, Part II, which also contains summarised accounts of each factory.

sources of supply were also explored and orders were placed by which their prospective capacity was called into play. Great as was the effort the result fell short of expectations, and far short of the rapidly increasing demands. First here then there it became necessary to create or organise further capacity at Government cost.

The new emergency state factories thus owed their inception not to any definite plan or policy of state monopoly but to the immediate stress of practical necessity. They came into being as additional to existing sources of supply, not in substitution for them. Throughout the war they worked side by side with trade factories, and in most cases their products were the same as those produced under contract.

Actual priority in order of time belongs to certain factories initiated during the winter of 1914–1915 for the manufacture of high explosives, the supply of which had not previously been undertaken in a national arsenal in this country. In the spring of 1915, these were followed by National Shell Factories, many of them establishments converted from other uses and organised for the supply of the lighter types of field gun ammunition, the demand for which seemed ever to grow beyond calculable limits. The new Ministry of Munitions undertook in the summer of 1915 the creation of National Projectile Factories, huge establishments erected and equipped *ab initio* for the supply of heavier types of shell the need for which was now multiplied by reason of the new programme for the equipment of the Army with heavy artillery on a greatly improved standard. Parallel with the National Projectile Factories and based on the same programme there sprang into existence National Filling Factories, establishments on a scale previously unknown in this country, a single one of which occupied an area of one square mile. Explosives factories had also to be replanned and developed in proportion.

Certain explosives factories had their origin later, but with this exception it may be said that the new national undertakings initiated and erected during the years 1915 and 1916 sufficed to carry out to the fullest extent the enlarged gun ammunition supply programme, which, as the event turned out, reached its climax in 1917, after which a limit on expansion was set by the limited availability of essential materials.

The national factory developments of 1917 and 1918 were more varied in character, and were governed less by any technical advantages anticipated from bulk output than by the ever increasing economic stringency which in these years conditioned all forms of industrial enterprise. As the commercial control exercised by the Ministry of Munitions increased in intensity by reason of the need for restricting importation and for securing the most economical allocation of materials, the position of the State as industrial producer became more and more predominant, and its command over material and over labour concentrated in its hands the power of initiation and development to an extent not previously contemplated. Many of the new departures of this later period were devised to satisfy demands the relative urgency of which had hitherto been less marked. Salvage

depots on a huge scale were required for diminishing the waste of valuable industrial materials or warlike equipment. Factories for the repair of guns, for the provision of gas warfare supplies, both offensive and defensive, and many miscellaneous establishments were also initiated or enlarged. Lastly the rapid development in aerial warfare led to the creation of a fresh series of factories pursuing an industry which may almost be said to have been non-existent when war broke out and in which there was consequently little or no private trade capacity to fall back upon, the manufacture of aero-engines and of aeroplanes.

This chapter will trace in outline the chronological development of these various undertakings established or managed by Government agency.

II. National Factory Projects before the Establishment of the Ministry of Munitions.

The almost entire lack of factories capable of supplying high explosives, together with the number of experiments which were being made as to their manufacture and the extremely technical nature of the whole industry, led to earlier and more drastic action with regard to their supply than with regard to that of any other form of munitions.

The Committee on High Explosives established in November, 1914, by the Board of Trade at the request of the Army Council, recommended the strongest measures, including the control of the whole supply of raw material for the manufacture of T.N.T., the prohibition of exports and the seizure of a factory at Rainham erected for the manufacture of butyl alcohol, which could be converted to the purification of T.N.T. Before the recommendation of the committee could be carried out it was necessary to pass Sub-Section (3) of the Defence of the Realm Consolidation Act enabling the Admiralty or the Army Council to take possession of, and use, any factory where warlike stores or articles required for their production were manufactured. The powers taken were even then regarded mainly as a reserve in order to secure maximum output. The Act passed into law on 27 November, and possession was taken of the works at Rainham the next day. Rainham was thus the first factory to be nationalised after the outbreak of war.

The Committee on High Explosives under the chairmanship of Lord Moulton acquired full executive power at the end of December, 1914, and determined on a far greater programme. It was decided to erect a large national factory for the supply of T.N.T. at Oldbury, to be planned by and be under the control of the State during the initial stages of production only. Mr. K. B. Quinan, of the Cape Explosives Company, was summoned from South Africa to supervise its construction. It was built at lightning speed and had begun production by May, 1915. During the spring of 1915, it was agreed that Messrs. Chance and Hunt, to whom the factory was to have been transferred on completion, should undertake its control as agents for the State, and not as contractors in conformity with the first intention. This factory was the great achievement in the way of a national factory which preceded the Ministry of Munitions, and if it did not

actually serve as a model for other factories, its erection indicated possibilities for further action and secured the services of Mr. Quinan, which were invaluable in the design of Queensferry and Gretna. The Committee on High Explosives began in May, 1915, to instal guncotton plant at Queensferry on behalf of the Admiralty, and shortly afterwards instituted search for a site, finally found at Gretna, for the production of propulsive explosives for the Army, but the Ministry of Munitions was responsible for the production of T.N.T. at Queensferry and for the whole layout of Gretna. Still, the policy of establishing these national factories belonged to a period preceding the formation of the Ministry.

The most notable remaining project of this period (August, 1914, to June, 1915,) was the Admiralty scheme for the Royal Naval Cordite Factory at Holton Heath. This new national factory was erected by that Department and remained under its control throughout the war. It owed its inception to a desire for departmental independence and to the unwillingness of cordite firms to enter into any agreement whereby the Department should retain possession of plant after the war, even though practically the whole cost had been borne by the State.

Another remarkable development of this period was the erection of wood distillation factories by the Office of Woods and Forests. A small state-owned acetone plant at Coleford, originally established in 1913, for utilising waste wood from the Crown Forest of Dean, was extended early in 1915, at the instance of the War Department, and supplementary factories were established at Dundee and Bideford. One contractor only was induced to erect wood distillation plant at Longparish, and this factory also was eventually nationalised (early in 1917).

Mention should also be made of the various explosives factories which were subsidised by the State and afterwards taken over as national factories. The inception of these works belonged to the early months of the war, and they were taken over after the formation of the Ministry, usually on the ground of indifferent output.[1]

In addition to the pioneer explosives factories, a second class of national factories had come into existence before the summer of 1915. These were the National Shell Factories. Placed under an unique system of management, and consisting for the most part of existing premises acquired and equipped during 1915, or the early part of 1916, they present a curious contrast to the National Explosives Factories, the only other national factories of which any representatives existed in pre-Ministry days. The latter, subject to almost every different form and degree of Government control, taken over as often as not from firms which were not working them satisfactorily, established at irregular intervals throughout the course of the war, can hardly be said to have been constructed according to any definite programme.

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[1] See below, p. 46.

With the National Shell Factories matters were different. As the needs of the Army outgrew the augmented resources of the armament firms and the Ordnance Factories, energetic measures were taken to open up new sources of supply. By the end of April, 1915, it had been decided that National Shell Factories should be established for the manufacture of the smaller natures of shell, and the local committees which were springing up in important engineering districts were invited to undertake the control of these factories through specially appointed Boards of Management. The Leeds Committee led the way, hoping that the concentration of resources in a single national factory to be operated under one management on a non-profit basis would overcome many of the difficulties in regard to machine tools, supervision and inspection which were being experienced. The scheme for the Leeds Shell Factory was approved on 7 May, 1915.

By the close of June, seventeen factories of the same type were approved, and by the end of the year schemes were ripe for the establishment of some thirty factories under local management boards. The programme was quickly made, the factories quickly determined on. By the summer of 1916, the tale of National Shell Factories was to all intents and purposes complete.

This promptitude was partly due to the obvious urgency of all measures which would increase the existing means of satisfying the Army's constantly growing need for ammunition. Partly, also, the Government was anxious to make use of the free services so generously offered by business men all over the country; it was felt that the management of a factory was a matter on which they could get to work at once, and in which their expert knowledge would be invaluable. Consequently the management of a factory was offered as an alternative, or as an addition, to the scheme for local administration of shell contracts in certain districts.

The National Shell Factory programme thus was swiftly conceived and rapidly carried into effect. The factories fully demonstrated the adequacy of this system for providing the addition to the output of light and medium shells for which they were originally planned. As time went on no necessity arose for the building of more factories for these types of shell; the extension of old ones proved sufficient. And in the greater number of the National Shell Factories the maximum output attained considerably exceeded the original estimates.

Yet it was not to be expected that so many factories, equipped at so great speed, placed under a form of management so new, should be completed without difficulty. Relations with headquarters had to be defined; provisions for the supply of machinery and labour had to be made, trade jealousies and secrecies had to be broken down before the scheme could work smoothly. Sometimes the personnel of the directing Board was wrong; sometimes friction with officials of the Ministry was hard to overcome; sometimes the work was hindered by changes in the orders received.

Nevertheless, it should be remarked that, although there were many cases in which difficulties loomed large at the beginning, and many in which deliveries were belated, there were hardly any which did not

finally attain a large measure of success. In the single instance where an unsuccessful project was eventually abandoned, failure was due rather to the peculiar circumstances of the factory than to the conditions common to the National Shell Factories. The fact that there were no other notable failures must be taken as a proof of success where so many factories were concerned. But at the outset the bulk of these factories failed to fulfil expectations ; deliveries began slowly and, with certain conspicuous exceptions, costs were high. The general high costs were especially disappointing in view of the fact that certain of the factories had succeeded in manufacturing at a very low cost, and that the Boards of Management accepted no fee for their work. Delays and the variation in the costs of raw material, etc., paid by the different factories were partly attributable to lack of co-ordination and, in some cases, to the preoccupation of members of the Board of Management with concurrent projects for co-operative manufacture.

Centralised buying and centralised control brought down the costs ; even as early as March, 1916, it was found that all types of shell made in the national factories, with the exception of 6 in. H.E., could be produced at a price below contract rates, and six months later all kinds of shell from the national factories were being supplied more cheaply than in the outside market. But the attempt to make exact estimates of the sums saved by the institution of National Shell Factories was abandoned fairly early because of the many conflicting factors that entered into the reckoning. On the one hand, the factories gained by free expert management and supervision and in some cases by obtaining buildings rent free, as at Wrexham. On the other hand, they were frequently handicapped by poor equipment. The Boards often tried to make use of machinery which could be obtained at once and in the neighbourhood, and which was often ill-adapted to the purpose to which it was put. The great haste in which the factories were adapted and equipped sometimes resulted in a bad layout, a permanent disadvantage not to be overcome by any reorganisation.

A considerable strain was placed on the National Shell Factories by constant changes in the nature of the orders presented to them. The factories showed great powers of adaptation. They were designed to produce light shell, and 18-pdr. and 4·5 in. shells were more generally produced than any other type ; but when the supply of light shell had for the time overtaken demand, as in the summer of 1916, they turned over to other work and manufactured the larger natures of shell or components for larger natures.

For the most part these factories were situated in the North, where the local committees in large engineering centres nominated Boards of Management. London had only two small National Shell Factories, Ailsa Craig and College Park, and these did not originate in schemes after the Leeds model, but were the works of contractors under the Metropolitan Munitions Committee, which were brought under the Committee's direct control for particular reasons. The only other southern factory, at Bristol, assembled shell components

made locally, but did not manufacture shell. Wales had eight factories, five in the South, in the districts round Cardiff and Newport, three in the North, at Wrexham, Portmadoc and Carnarvon, of which the first had been established by the Liverpool Board of Management and was later handed over to the North Wales Board. In Ireland there were factories at Dublin, County Galway, and Waterford, the last being for the manufacture of cartridge cases. Dublin had three factories, one a fuse factory, at first attached to, but later separated from, the shell factory, at which 18-pdr. shell was the chief product. The third factory was devoted to the manufacture of heavy (9·2 in.) shell, but it remained with the other shell factory under the control of the Dublin Munitions Committee. In Scotland there were two National Shell Factories, Aberdeen and Dundee; of these, that at Aberdeen was among the few shell factories nationalised as late as 1917. It was originally owned by a private firm, but its manager was convicted of malpractices, and the Ministry, while cancelling the contract with the firm, felt it important not to interrupt output and so decided to convert it into a national factory. The Dundee factory was exceptionally well planned and proved particularly agile in turning from one class of work to another.

For the rest, the list of factories is almost a list of northern manufacturing towns, such omissions as there are being for the most part rectified by a list of the National Projectile Factories. The Liverpool Board of Management was responsible for the establishment of an unusually large number of factories: in addition to the four factories in Liverpool (Haymarket, Cunard, Edge Lane and Lambeth Road), it undertook the management of the Bootle factory, sanctioned the plans for the Chester factory, and initiated the factory at Wrexham. Other Boards were for the most part responsible for the management of only one shell factory. Something should, perhaps, be said about the Leeds factories. Of these, there were three shell factories; in point of fact the heavier type of shell was manufactured in them, and until 1918 they were classed as Projectile Factories for purposes of headquarters administration.[1] The Leeds Board of Management, however, having been the pioneers of similar boards throughout the country and having started these factories, retained complete control of them for a considerable time and some measure of control to the end of the war.

The inception of this great group of factories belonged to pre-Ministry days. But the services rendered to it by the first Minister of Munitions should be acknowledged. Mr. Lloyd George, as Chairman of the Munitions of War Committee, gave the principal ministerial impulse to the inception of the scheme before the Ministry of Munitions was created. Later, he did much by his visits to manufacturing centres to encourage the formation of Boards of Management; his authority and initiative expedited production; the conferences held under his chairmanship solved difficulties and evolved practical methods of working.

[1] During the last year of the war the Leeds factories were classed as National Ordnance Factories.

III. The Construction Period, 1915–1916.

The National Shell Factories were established to meet one part of the Army's urgent need for gun ammunition. The vast programme for gun ammunition production launched by the Ministry of Munitions shortly after its creation in June, 1915, was only capable of fulfilment by the establishment of new manufacturing capacity. During the summer of 1915, projects were started for two new classes of national factories. These were the National Projectile Factories and the National Filling Factories. In addition, the number of the National Shell Factories was increased, as has already been seen, while corresponding extensions were made to the existing capacity for State manufacture of explosives. The problem of producing industrial equipment was attacked simultaneously with that of shell manufacture. The first nationalisation of factories for gauges and small tools took place in the autumn of 1915.

(*a*) National Projectile Factories.

The National Shell Factory programme was designed to meet the need for light shell, but with the adoption of the very large programme for heavy guns and howitzers resulting from the Boulogne Conference (19 June, 1915) the need for heavy shell became equally urgent. Indeed, as time went on there was a growing tendency for the proportion required of heavy to light shell to increase as additional heavy guns came into the field. And with this tendency plant was often turned from the manufacture of light to that of heavy shell, 6 in. being made where 4·5 in. had been made before and so on. But before such adaptations became possible some method had to be found of increasing the supply of heavy shell, since it was clear that even if existing trade facilities were pressed to the utmost the output would fall very far short of what was needed.

Consequently, a month after the Ministry had been formed, a conference was held, under the chairmanship of Sir Percy Girouard, between representatives of the Ministry and of nine armament firms, whose co-operation was solicited, and by the end of July, 1915, a programme for the establishment of National Projectile Factories had been prepared and accepted. Sir Percy Girouard said at the conference held on 18 July that it was evident:—"That the firms could not increase in any material degree upon their present promises with their present plant," and that "the total of all their anticipations would not come up to anything like the requirements of the Government." It appeared that the quantity of heavy shell required was likely to be four to five times as great as the quantity which could be supplied by existing firms.

The chief difficulties anticipated in the establishment of National Projectile Factories arose from the growing scarcity of machinery and labour and the need for finding competent management for the new factories without impeding the development of existing organisations. These points were to some extent met by the scheme which was finally adopted. Raw material was to be provided, and plant and machinery paid for by the Government, which was also to help

in securing labour. The management was to be in the hands of experienced firms. Working thus with the firms it was hoped that undue competition for machinery and labour would be avoided, and that the fullest possible use would be made of existing organisations.

Some days were spent in the discussion of suitable rates to be paid to the firms for the work they undertook (Messrs. Cammell Laird, Nottingham, refused remuneration of any kind), but on 30 July Mr. Lloyd George approved a draft memorandum confirming the final decisions of the Ministry and the firms. Nine armament firms immediately began the construction of National Projectile Factories; by the middle of November five more were engaged in the same work. That construction should have begun in fourteen factories within five months of the scheme's first being mooted says much for the energy and initiative of those concerned. The only later additions to this group were certain factories the control of which was transferred, in some cases as late as 1918, from contractors or from other sections of the Ministry to the section responsible for National Projectile Factories.

As in the case of the National Shell Factories, deliveries were delayed beyond anticipation; means of co-ordination had to be worked out and methods of central buying developed. With the intensity of the demand for ammunition for heavy guns, impatience for delivery became great. Good methods of supplying labour, raw material and machinery were finally established, and the success of the work done by the National Projectile Factories may be gauged by the fact that the output of all exceeded the original estimates.

The administration of the National Projectile Factories and the relations of the management firms with headquarters were developed in a systematic and successful manner. Careful methods of costing and examination of all orders by the Ministry resulted in prices that were very satisfactory as compared with contract prices. There were no real failures; Birtley was transferred from the management of a private firm to direct management, not because the firm could not work it satisfactorily, but because the Belgian Government had agreed to staff it with Belgian labour and preferred to deal directly with the Ministry of Munitions. This was the only National Projectile Factory in which there was any departure from the system of management inaugurated at first.

The difficulties facing the factories were many; as soon as those arising from the lack of co-ordination had been overcome they were faced with others arising from the lack of forgings, of components and of labour, the shortage of which, as of raw material, became more acute in the last years of the war. Constant changes in orders also had to be dealt with. But after the summer of 1916, when their initial output fell below expectations, these factories fulfilled their functions.

(*b*) National Filling Factories.

At a conference held between the Ministry of Munitions and National and Assisted Projectile Factories, in April, 1916, Mr. Lloyd George, in urging the necessity of speedy deliveries said:—"I am

bringing the same pressure to bear upon the filling factories, but the filling factories sometimes say to me, 'Well, it is no use our forging ahead unless we get plenty of empty shell to fill.'"

A scheme for constructing filling factories had been launched at the same time as that for constructing projectile factories. In this case no conferences with contractors were needed. The filling of shell was not regarded as the monopoly of any group of firms, since practically the whole of the actual shell filling had been carried out in the Royal Laboratory at Woolwich, although a certain amount of component filling was done in some of the large armament and explosives factories. Therefore when it became evident that existing facilities were unequal to the demand a new section of the Ministry was formed in July, 1915, to deal with the problem of gun ammunition filling. On 23 July it was decided at a meeting held under the chairmanship of Mr. Lloyd George that arrangements should be made with firms to build and manage filling factories on behalf of the Government.

It had already been suggested that the neighbourhood of Leeds was suitable for a filling factory, and the Leeds Board of Management had expressed its willingness to undertake the construction and management of the factory, a site being selected at Barnbow. This plan was developed, and the Boards of Management in Liverpool, Glasgow and Gloucester were invited to follow the example of the Leeds Board. These four factories constructed under the supervision of local boards were all designed for the assembling of quick-firing ammunition and for filling breech-loading cartridges with propellants. Construction began at Leeds and Glasgow (Georgetown) in September, 1915, and at Liverpool and Gloucester in October.

Factories of other types were needed. Five, at Chilwell, near Nottingham, Morecambe, near Lancaster, Newburn, near Lemington (Northumberland), at Otley near Leeds, and at Banbury were designed for filling large shells. Six, at Coventry, Perivale, Southwark, Hayes, Abbey Wood and Cardonald, were planned for the filling of fuses, gaines and other minor components. All these factories, with the exception of Newburn, Otley and Banbury, were in process of construction by the end of December, 1915. The construction of Perivale was entrusted to the Metropolitan Munitions Committee; the others were placed under the control of firms acting as agents for the Ministry or of managing directors appointed by the Ministry.

Some delay was experienced in the building of these factories. The selection of the site alone was no easy matter. Proximity to shell producing areas was desirable, yet owing to the dangerous character of the work it was not advisable to have the factories too close to any great centre of population; it was essential to have good railway services, and important that the railway communication with ports of shipment should be direct; finally, the nature of the work required ground especially adapted to a good layout. It was small wonder that several sites were selected and rejected, or that on account of the speed with which new work was carried out some of the sites finally chosen were not entirely suitable and involved the Government in considerable expenditure, in some cases, on the drainage of land, the making of

roads and other similar work. Very considerable difficulty was also experienced in the case of factories for filling larger natures of shells, since neither the nature of the explosive nor the methods of filling to be used were finally settled until the end of January, 1916.

These obstructions did not seriously affect the factories for component filling or for the assembling of Q.F. ammunition. Southwark, indeed, an emergency factory, converted from a large warehouse, was in working order in September, 1915, within three weeks of its commencement. The establishment of the others was not so swift; Southwark, Hayes and Perivale alone had begun regular output by the end of the year; but as for purposes of safety many of the factories were built in self-contained units, it was possible for output to begin from one part of the factory long before the whole was finished. A serious endeavour was made to expedite the completion of the filling factories during the early months of 1916. The projects for Otley and Newburn were then abandoned in favour of more promising schemes, for filling heavy shell, which were undertaken by the managements of the Leeds, Liverpool and Glasgow, Q.F. Filling and Assembling Factories.

As a result of these efforts the National Filling Factories mostly started operations in the spring of 1916. Chilwell, the largest of them, built for the loading of heavy shell, was at work in January, 1916, and had previously worked out methods of filling for general adoption. Output from three others also began in January. Most of the others were working by the end of March.

The 1915 programme supplied the Government with almost all that was needed in the way of National Filling Factories. Few were added to the number later; in June, 1916, the building of a factory at Hereford was begun as an understudy to Chilwell, because the work done by Chilwell was so important that it was thought necessary to have a factory to take its place in the event of its being destroyed. From November, 1916, to April, 1918, the Hereford factory was in operation. It was then closed, but maintained as a stand-by to Chilwell. In July, 1918, the fears which had led to its erection were justified, for a serious explosion occurred at Chilwell, and the Hereford factory was re-opened. Rebuilding began at once at Chilwell and the factory was at work again within a remarkably short time.

An additional fuse-filling factory was established at Luton during the winter of 1916–7. A shell-filling factory at Pembrey, erected by the Explosives Loading Company early in the war, was nationalised at the same time as an adjacent explosives factory from January 1917. In November of the same year the building of two new filling factories began. One, at Gainsborough, was designed to do naval work of a secret nature, filling sinkers with T.N.T., and was controlled directly by the Ministry. The other, at Chittening, was for the filling and assembling of H.S. (or mustard gas) shell, an extremely dangerous process; at first it was intended that the factory should be managed by Nobel's Explosives Company, but the peculiar nature of the work and the labour difficulties which were anticipated led the Ministry to substitute the method of direct for that of agency control. These were

the chief additions to the National Filling Factories after the beginning of 1916. They were mostly erected to meet new needs as they arose.

The main characteristic of the filling factories was the elaborate system of precautions to prevent injury to workers' health through the handling of T.N.T., tetryl and other explosives, and to avoid the dangers of explosion. The filling factories with the explosive factories suffered from these risks. Mention has been made of one of the most serious of the explosions during the war which occurred at Chilwell. An explosion at the Leeds Filling Factory in December, 1916, caused considerable loss of life. A fire at Morecambe in October, 1917, annihilated the buildings, and the Explosives Factory at Rainham was also destroyed by fire in February, 1918. No other explosions or fires on a large scale in national factories are recorded, and considering the magnitude of the work done it may be said that on the whole the various safety measures taken were successful.

During the year 1916 the National Filling Factories passed successfully through a very difficult period of their existence. The training of an unprecedented number of workers in the careful performance of numerous trifling operations was in itself no easy task. Its difficulty was increased by the novelty of many of the processes and the unfamiliarity of the supervisory staff with this class of work. The quality of the work done improved as the year went on. The most remarkable instance of failure in efficiency was rectified when once the origin of faulty and dangerous ammunition had been traced. During the last two years of the war the filling factories contributed much towards a general raising of the standard of quality in gun ammunition.

(*c*) Trench Warfare Filling Factories.

The problem of filling trench mortar ammunition was considered at the same time as that of filling gun ammunition, and it was decided that factories should be built at Denaby, Erith and Watford, of which the last should be a national factory. It was, however, found difficult to make suitable financial arrangements for the working of the Denaby and Erith factories. Accordingly they were nationalised in January, 1916, the former being operated under a particularly successful agency agreement and the latter brought under the direct control of the Ministry, as was the case with the Watford factory. Output began from Erith and Watford in October, 1915, and from Denaby in December. All these factories were complete in February, 1916; in the same month a factory at Fulham engaged on similar work was nationalised on the ground of unsatisfactory safety conditions, and the building of a second government factory at Watford was begun. This last factory, Watford No. 2, in addition to filling trench mortar bombs, was used for the assembling and filling of aerial bombs and for assembling chemical shell until this last work was taken over by the Greenford Chemical Shell Assembling Station in January, 1917.

Continual changes were made in the work done by these factories, but with many alterations in demand and numerous developments in the work of the Trench Warfare Supply Department, they showed great adaptability and responded readily to the varying claims upon them.

(*d*) Additions to Explosives Factories.

The first activities of the Ministry with regard to explosives factories were devoted to the development of schemes already projected, and were diversified by the acquisition of factories already built. The work at Gretna was carried out with great energy under the direct supervision of Mr. Quinan ; the original scheme, which had been for an output of 2,000 tons of cordite per month, was enlarged with the idea of producing 3,300. The buildings were scattered over a site of nine square miles, at some distance from any large centre of population, and included new townships for the workers, of whom there were at one time 20,000. The utmost celerity could not produce speedy deliveries from a factory in which every building to accommodate both the plant and the labour had to be created from the beginning. Output from some portions of the plant began in June, 1916, and in the following August all processes were being carried on.

The plans for the factory at Queensferry were also extended, part of the site being devoted to sections for the production of T.N.T. and tetryl in addition to the guncotton section. Arrangements were also made with the Asiatic Petroleum Company for the erection of a factory at Sandycroft, near the T.N.T. section, for the production of M.N.T., and this factory was in 1918 incorporated with Queensferry.

The activities of the Explosives Department were chiefly occupied with the development of the important factories projected or begun before the Ministry was created. Other factories were erected during the first year of its existence, but none on so large a scale as Oldbury, Queensferry, Gretna and Pembrey. The erection of the State picric acid factories did not begin until 1917.

Still, when any deficiency had to be made good, the Ministry decided upon the erection of new State factories. In June, 1915, a factory at Penrhyn Deudraeth, for the manufacture of T.N.T., which was being erected by a private company largely at the expense of the State, was destroyed by an explosion. The company could not undertake the cost of rebuilding, the Ministry felt it imperative to replace the lost capacity and at once took over the site and rebuilt the factory, the first deliveries from which were made in January, 1916. In August, 1915, the building of a State factory for the production of ammonal was begun at Watford ; for the most part the Government depended on trade sources for the product, and it was thought well that part at any rate should be manufactured in a national factory. Many different explosives were produced at this factory later. The first deliveries were made in December, 1915.

The erection of a factory at Langwith was begun in November, 1915, so that England should cease to be dependent on Sweden for supplies of ammonium perchlorate. Considerable difficulties were experienced in the working of different sections, and it was not until nearly two years after its inception that there was any output from the factory. By the discovery of simplification in processes smooth working was finally attained and full output was reached in July, 1918. A more speedily successful venture was begun in October, 1915, at Trafford

Park, for the production of pure toluol. The factory was working satisfactorily in July, 1916, and the output far exceeded the original estimates.

Messrs. Brunner, Mond & Company, had, in the spring of 1915, undertaken to erect plant for the manufacture of ammonium nitrate, and under their supervision a group of factories was built near Northwich. The Government had promised to supply them with calcium nitrate from Norway, but the supplies from that country proving inadequate it was decided to resort to home production. Accordingly the Ministry entered into negotiation with the Salt Union Company, Ltd., for the acquisition of the Victoria Salt Works, acquired additional land under the Defence of the Realm Act, and in February, 1916, proceeded to equip H.M. Factory, Victoria, as a national factory for the production of calcium nitrate. In August it was able to deliver supplies from this factory to Messrs. Brunner, Mond & Company's ammonium nitrate factories, which were in the immediate neighbourhood.

Ellesmere Port and Craigleith were planned in the spring of 1916. Of these Ellesmere Port was erected for the manufacture of phenol, to be used in the production of picric acid. For the most part the production of phenol was, like that of picric acid, in the hands of private firms. But towards the end of 1915 it was feared that trade capacity for the output of phenol would prove inadequate and the construction of a factory at Ellesmere Port was decided on. It was begun in March, 1916, and completed in February, 1917, scarcity of labour and alterations in design being responsible for some delay.

Craigleith was the last national factory erected for the production of T.N.T. Its capacity was small as compared with Oldbury or Litherland, being only for the production of 50 tons a week. It was, in fact, designed to replace the output from a small neighbouring factory which had been worked by the Lothian Chemical Company with considerable success, but was situated in a dangerously congested area. The company consisted of two chemistry professors from Edinburgh University, and of a works manager with practical experience. The construction of the Craigleith factory was entrusted to them. It was begun in April, 1916, and the first deliveries were made in February, 1917.

By the summer of 1915, experience had shown the impracticability of certain earlier trade projects for explosives manufacture. Accordingly, the Ministry added to the factories which originated as national undertakings certain works where trade ventures had been subsidised by the State but had not met with success. These included a T.N.T. factory at Hackney Wick, purchased from the contractor in July, 1915, West Gorton and Litherland, which were taken over under the Defence of the Realm Act in October, 1915, and March, 1916, respectively, and the Sutton Oak phenol works. These last had been acquired by the United Kingdom Chemical Products Company in February, 1915 and had been subsidised by the Government in April with a view to extensions of plant. Progress was unsatisfactory in this factory, and after a series of agreements the works were taken over

in January, 1916, the Department purchasing the company's shares. The King's Lynn acetone factory was nationalised in March, 1916, for very similar reasons.

Two cases stand by themselves. The Gadbrook factory for T.N.T. purification was designed and erected by Messrs. Brunner, Mond & Company in June, 1915, but was subsequently accounted a Government factory in view of the specially dangerous nature of the operation and in order to secure its exemption from the terms of the Explosives Acts. In the autumn of 1915 it was agreed that Messrs. Nobel's explosives factory at Pembrey should be nationalised as from the beginning of 1917, on account of the complexity of the agreements with the firm and the large proportion of the capital expenditure already borne by the State. The Admiralty in the first instance entered into negotiations with Messrs. Nobel's for the construction of a factory for propellants which should be operated as a trade factory. Matters were delayed owing to the difficulty of making satisfactory financial arrangements and in February, 1915, the Admiralty cancelled its agreements with the firm, substituting the plans for the Royal Naval Cordite Factory. The War Office had already undertaken to subsidise T.N.T. works which Messrs. Nobel's were to erect at Pembrey. In July, 1915, the Admiralty entered into further negotiations for manufacturing cordite at the same place. The schemes expanded considerably after the Ministry of Munitions was created. In October, 1915, the various contracts were amalgamated for the sake of simplicity and the firm undertook to operate the factory as contractors until the end of 1916, and subsequently as agents on behalf of the State. At the same time the Ministry undertook the whole of the expenditure, instead of seven-tenths as previously agreed.

Of twenty-three National Explosives Factories erected or in process of erection by the summer of 1916, eleven were originally built as State and twelve as trade factories, but of the latter Pembrey was the only one which vied in importance with those projected in the first instance by the State. The building of Craigleith marks the end of those belonging to the first programme of explosive supply. Later developments will be described below.[1]

(*e*) National Gauge and Tool Factories (1915–1917).

As early as July, 1915, it was proposed to establish a central gauge factory under headquarters control. The project did not materialise, but the agreements which were subsequently made with certain firms for an extended output of gauges and small tools brought these works under an exceptional degree of control which practically placed them within the category of national factories administered by agents. The first of these was the Birmingham Small Tools Factory, nationalised in September, 1915. It was followed closely by the Croydon Gauge Factory under an agreement of November, 1915, and similar arrangements were made with the Woolwich Gauge Factory in August, 1916. Two more gauge factories, the Wolseley Motor

[1] See below, p. 50.

Company's Works in Pimlico and the Newall Engineering Company's at Walthamstow were nationalised in 1917 and 1918 respectively, and a factory at Kilburn was established as a national undertaking for the employment of enemy skilled labour in May, 1917.

There was no general scheme for establishing new national tool factories for meeting the general shortage of small tools experienced in 1916. One State factory only was established and two existing factories were nationalised. The Gateshead spade-cutter factory was set up in May, 1916, to make a tool of which the supply was specially difficult. A general tool factory at Westminster was nationalised in 1917 with a view to reorganisation and to improvement in output. In September, 1917, the works of the Hoffman Manufacturing Company were purchased by the Ministry in order to overcome the difficulties experienced in providing ball-bearings for the new aircraft programme. The company had already undertaken considerable extensions and were unwilling to bear the risk of any further expansion in view of post-war prospects. They, however, placed the technical ability of their management at the service of the State.

IV. Further Developments to meet the Demands of 1916.

It has been seen that the great factories erected for gun ammunition supply during 1915–1916 sufficed to meet the needs of the Army in this respect. During the year 1916, while these undertakings were starting up, fresh national projects were launched with a view to supplying other classes of munitions. These, and the later factories established by the Ministry, were very miscellaneous in character, some rendering minor services, some providing only a small proportion of the total product used by the Government, but some of considerable importance. Of those which were initiated in 1916 perhaps the most prominent were the Government Cartridge Factories and the Government Rolling Mills.

(*a*) Government Cartridge Factories and Rolling Mills.

In March, 1916, three trading small arms ammunition firms undertook to erect Government factories for the manufacture of cartridges. The King's Norton Metal Company became responsible for one at Blackpole, Worcestershire, the Birmingham Metal & Munitions Company for another at Blackheath, and Messrs. Eley Brothers for a third at Edmonton. Construction began at Blackheath and Blackpole in the spring but was delayed at Edmonton until August. A fourth similar project was undertaken by the Chief Superintendent of Ordnance Factories at Woolwich. A fall in the demand for the products led early in 1917 to the reduction of capacity to one half. In spite of changes in the kind of product required from these factories, that at Blackpole was extremely successful; greater difficulties were experienced at Blackheath, and though the factory attained a respectable output it tended to lag behind expectations. The factory at Edmonton was the least successful, construction began late and was slow, hopes of reaching maximum output were never fulfilled and

while the other factories adapted their product to changes in requirements, the Edmonton factory ceased production of cartridges, and was transferred to aero-engine repair work in March, 1918.

The decision to erect National Rolling Mills followed on that to erect Government Cartridge Factories. The inferior quality of brass supplied by private mills, and the difficulty of securing adequate supplies of cupro-nickel strip convinced the Government that the desired output of small arms ammunition could not be attained without strong measures being taken to improve the supplies of strip.

Southampton was thought to be a suitable site for the Government Rolling Mills on account of transport and labour facilities, and a great scheme was launched in March, 1916. Certain operations began in November, 1916, but owing to the reduction of demand at the beginning of 1917 the factory was never worked to its full capacity. One result of the decreased output was that manufacture was not as economical as had been expected, and in January, 1918, the cost of production was considerably higher than that of any trade firm. Costs were, however, reduced during 1918. The quality of the output was throughout very high.

(*b*) National Factories for Chemical Warfare.

In the spring of 1916 the British Government approved of the use of lethal chemicals in artillery shell, and provision had to be made for the dangerous processes of charging the shells with chemical mixtures, and assembling the charged shells with their bursters and (in some natures) with their cartridges. The former operation was mainly undertaken by trade factories where the chemicals were made; the latter was restricted to national factories, where the conditions as to health and safety could be imposed in the same way as in the National Filling Factories.

A contractor's factory at Walthamstow which had been engaged in the filling and assembling of lachrymatory shell and grenades undertook temporarily the work of assembling lethal shell and was nationalised in June, 1916, but the work of assembling was shortly afterwards transferred, first to the Royal Laboratory, Woolwich, and later to Watford (Trench Warfare Filling Factory) No. 1. In August, 1916, the construction of a national chemical shell factory was begun at Greenford and output began in January, 1917; considerable extensions were carried out later.

A different policy was at first pursued when, in the autumn of 1917, plans were made for the establishment of the first mustard-gas factory at Chittening as a trade factory for making and charging the gas and also for assembling the shell. Construction of the factory began in November, 1917, but, mainly in order to facilitate administration and also to make use of plant at Avonmouth, the work of manufacture was transferred to the picric acid section of the latter factory, and the charging and assembling of the shell was carried out at Chittening, which was completed as a State factory, under the direct control of the Gun Ammunition Filling Department.

These factories, Walthamstow, Greenford, and Chittening, were the only ones set aside for this particular work which involved the

handling both of explosives and chemicals, although during the last year of the war a certain small proportion was undertaken in the ordinary filling factories with a view to utilising spare capacity. The manufacture of chemicals by the trade continued, except that Avonmouth was regarded as the main source of supply for mustard-gas and that a chemical factory at Middlewich was nationalised in August, 1918, with a view to improving output. Towards the end of the war some work upon chemicals was also undertaken by certain of the national explosives factories, where suitable plant had been set free through changes in programme.

The first national factory for anti-gas purposes was not established until 1916, as the original policy of the War Office authorities was to rely upon the efforts of the two firms (Messrs. Bell, Hill and Lucas, and Messrs. James Spicer and Sons) who placed their resources at the Government's disposal immediately after the first gas attack in May, 1915. In 1916, however, a State factory for granule production was established by the War Office at Stamford Hill and began production in February, 1917. In August, 1918, after the Ministry had undertaken responsibility for the supply of this apparatus, two new national factories were set up for the manufacture of a new type of respirator at Holloway.

(*c*) Additional Explosives Factories.

In the summer of 1916 it became evident that if the demand for explosives came up to what was expected, foreign and trade resources would be insufficient to supply the nitrocellulose powder needed as a propellant, while the use of additional quantities of picric acid seemed imminent. Accordingly some new national factories were begun.

Of these, two, Henbury and Irvine, were for the manufacture of nitrocellulose powder, and were intended to render the country independent of uncertain supplies from America. Building operations began at both in January, 1917, but the entry of the United States of America into the war in April, 1917, completely changed the position of affairs with regard to this product. It was far less expensive to make it in the United States of America, because of the large quantity of imports needed for its production in England. Consequently work at the Henbury factory was reduced in April and given up altogether in May, 1917. The factory at Irvine, however, which was constructed and managed by Nobel's Explosives Company, the only firm in the country which had any previous experience in the production of nitrocellulose powder, was proceeded with and made its first deliveries in February, 1918. The work of construction was slow and full output was not reached before the Armistice. No other national factories were built for the manufacture of propulsive explosives.

For the production of ammonium nitrate a factory was constructed at Swindon early in 1917. Up to that time the Government had mainly relied for this product on the factories belonging to Messrs. Brunner, Mond & Company, in the neighbourhood of Northwich, but it was thought these would be insufficient and the new factory was designed on a scale larger than that of either the Lostock or Sandbach works

erected by Messrs. Brunner, Mond. Some output was received from the Swindon factory in September, 1917, and considerable supplies were received from it during the summer of 1918, but it never worked to its full capacity.

It was in the planning of factories for the manufacture of picric acid that the most ambitious part of the Government schemes consisted in the last two years of the war.

Until the summer of 1916 the Ministry had trusted to trade sources for the supply of this explosive for which the demand seemed moribund. But when in 1916 the abandonment of picric acid was once more postponed and the supply of the raw material (phenol) was increased beyond expectation by the success of the synthetic methods introduced, the Government proposed to erect one vast factory capable of absorbing all raw material; the scheme was enlarged by a decision to lay down plant for fuming sulphuric acid in excess of that required for the picric acid. Construction was begun in September, 1916, on a site at Avonmouth commandeered under the Defence of the Realm Act. The scheme was not developed on the original lines; early in 1917 the picric acid programme was again reduced, mainly for financial reasons; the plans for making this explosive were cut down and the factory was never used for the purpose for which it had been intended. Ten units of the plant for fuming sulphuric acid were completed, and one of these began work in January, 1918, but demand diminished and the plant was closed down after working for seven months. Use was made in the summer of 1918 of the site and part of the picric acid plant for the production of mustard gas, to be used in the filling factory at Chittening. The practical difficulties of starting a new manufacture of this class were enormous. At one time the factory had to be closed because the vessels and baths were impregnated with sulphur, at another because almost all the technical staff were incapacitated owing partly to climatic conditions, which added to the difficulty of ventilation, and finally when mustard-gas was first produced it was so variable in quality that the Chittening factory found it anything but easy to handle. Labour casualties were numerous, reaching as high a proportion as 70 per cent. of the total workers employed in the manufacture, and this intensified the difficulty of securing labour which had from the first been great.

The Avonmouth factory was controlled directly by the Explosives Supply Department. Its history is a remarkable commentary on the change between the conditions in the spring of 1915, when the first explosives factories were constructed and brought into operation in a few weeks, and in the last two years of the war, when stringency of men, money, and materials hampered every new project. The persistence of the Department procured ultimate success in some part at least of the factory; a worse fate attended the concurrent plan for establishing at Billingham a large plant for utilising atmospheric nitrogen in order to secure some measure of independence of South American sodium nitrate. This scheme, after many vicissitudes and after constant examination by a series of financial committees, each one of which admitted its urgency and importance, was finally

postponed indefinitely in view of the difficulty of obtaining labour and materials. Its post-war value was generally admitted, and the factory site and plans were accordingly sold under special conditions to a commercial company for future development.

In order to utilise surplus quantities of raw material which had been produced by novel methods, three more factories were designed for the manufacture of picric acid. They were planned on a comparatively modest scale, at Bradley, Lytham and Greetland, and construction began in all these in January, 1917. In the winter of 1917 the demand for picric acid fell off abruptly; the factories were affected by this in different degrees according to the stage they had reached and their success in production. Building operations at Bradley had been delayed for various reasons; consequently it was decided to use this factory mainly for demonstration purposes. Later, arrangements were made for using the factory for a new process which had proved successful in the private works of the manager, Major L. B. Holliday, and the main work of the factory continued to be of an experimental nature until the close of the war.

The Lytham factory, under the management of Mr. Lance Blyth, made deliveries as early as July, 1917; but although full output was reached at a comparatively early date (November), the cost of production was considerably higher and the efficiency rather lower than in the other two factories. It was transferred to the direct control of the Explosives Supply Department in November, 1917. This change, however, did not secure economical working as compared with the remaining factories, and in March, 1918, when the picric acid demand was again reduced, the factory was closed.

The factory at Greetland was a conspicuous success, though some difficulty was experienced at first in laying the foundations. Production began in September, 1917, and the factory was so well designed and equipped that nitric acid was produced at £1 a ton less than at any other national factory; the costs of picric were continually reduced and the cost of raw materials for each ton produced was £28 less than at Lytham. As a result, when the production of picric was diminished early in 1918, Greetland was encouraged to continue, having proved itself one of the most economical sources of supply. The management was in the hands of Messrs. Sharp and Mallett, acting as agents for the Ministry.

No generalisations can be made about explosives and propellants factories; they were too various in type and too experimental in nature. All that can be said is that the need for explosives was met as it arose, and that it could not have been met without the institution of national factories.

(*d*) Sawmills and Box Factories.

The immense expansion in munitions production during 1916 put an unprecedented strain upon existing facilities for the production of boxes and particularly of cartridge boxes. During the year three national factories were established at Dagenham, Beddington and Woolwich for the manufacture or repair of wooden boxes, and a fourth, at Deptford, for tin box manufacture and repair. The establishment

of national factories was the effect of a definite policy, since it was expected thereby to overcome the difficulty experienced in placing contracts for a store which frequently changed in design and for which there were often emergency demands. Sawmills were also taken over from the original owners, who continued to operate the mills as Government agents. Five only of these were at work in the summer of 1917, but in October and November of that year numerous others were added, as a result of extensive felling operations instituted by the Board of Trade. By that date there were ten box factories in operation, an important part of their work being the remaking of boxes returned from overseas.

V. New Factories of the Period 1917–1918.

The national factories established during the years 1917 and 1918 were of extremely diverse character. State manufacture of explosive materials, such as cotton waste, was undertaken with a view to securing very close technical control over the quality of the product. The general shortage of materials led to the conversion of some of the earlier factories from shell production to ordnance repair, to the establishment of special factories for building materials and to a large expansion in the Government depots for salvage and repair. Manufacture of different novel stores was effected in national factories. An enormous expansion in the aeronautical programme was accompanied not only by the erection of new large scale factories for aircraft and aero-engine manufacture, but also by subsidiary national undertakings such as the Chelmsford ball-bearing factory, already mentioned above, and a machine-gun factory which was sanctioned in October, 1917, for the arming of aeroplanes and tanks, but did not begin production until after the Armistice.

(*a*) Cotton Waste Mills and Wood Distillation Factories.

The bulk of the cotton waste mills existing in this country at the beginning of the war were the property of the British and Foreign Supply Association, and in September, 1915, the Government subsidised the Association so that output should be maintained and the requirements of the national factories satisfied. In August, 1917, the Ministry bought out the Association and became the owner of the mills, retaining the directors as managers. Later it was thought well to establish a still closer technical control over the factories, and the directors resigned in May, 1918. From that time each of the mills was treated as a Government factory and directly controlled by the Propellants Supply Branch of the Ministry. The reorganisation of the mills which followed on their nationalisation resulted in great improvements of method and in more economical working.

In the autumn of 1917, three wood distillation factories were planned to provide the solvents needed in manufacturing aeroplane dope and to utilise waste wood from the large felling operations then begun. Construction of the first two of these factories, Mid-Lavant and Ludlow, began in the spring of 1918, but they had not reached the production stage before the Armistice, while at the third factory constructional work had hardly begun.

(*b*) National Ordnance Factories.

The enormous extensions made to the capacity for gun ammunition manufacture, mainly by the establishment of the national factories planned in 1915, resulted in a large increase in the ration of ammunition per gun. The life of the individual gun was thereby decreased, and by the spring of 1917 guns in the field were wearing out faster than they could be replaced. The obvious remedy was to turn over certain of the shell factories to gun repair or manufacture, and such a change could be more readily made in national factories than by the trade. Accordingly two National Projectile Factories at Sheffield (Messrs. Hadfield's), and Nottingham (Messrs. Cammell, Laird's) and a National Shell Factory (Leeds) began relining guns during 1917, and afterwards undertook gun manufacture. There was also classed among the National Ordnance Factories an entirely new establishment, which was set up at New Basford in December, 1917, for the manufacture of a new type of automatic gun, the 1½-pdr.

(*c*) Salvage Depots and Ferro-Concrete Factories.

The repair and re-manufacture of salvaged material was, to a large extent, undertaken by contractors, but the work of sorting the material took place at salvage depôts, of which five were established late in 1917, under the direct control of the salvage department of the Ministry. The National Box Factories, which have already been mentioned, undertook certain mechanical repairs. The breaking down of rejected ammunition was peculiarly dangerous work and was partly undertaken in the National Filling Factories, where capacity was freed by the reduction in gun ammunition production from the autumn of 1917 onwards. In the spring of 1918 the repair of gun carriages returned from overseas was effected, under the direct control of the Ministry, in an establishment at Southampton taken over from the inspection authority. As early as May, 1916, a national factory for the rectification and repair of fuses was established in the Gray's Inn Road, mainly on account of the difficulty of fixing contract terms for this class of work.

The need for economising all kinds of material was also met by entering upon various Government ventures for supplying materials for building and other purposes. A billet breaking factory had been established at Trafford Park, near Manchester, at the end of 1916, to deal with steel billets from America. It was directly controlled by the Ministry. It possessed the largest billet-breaking plant in the country and so was able to deal with half the imports of steel billets, the other half being distributed among different firms. At Merthyr Tydfil, rolling mills were established at Government expense in connection with blast furnaces, which were also taken over.

Early in 1918 two national factories were founded at Gotham, in Nottinghamshire, and at Yate, near Bristol, for the production of concrete and plaster slab. Both were erected and managed by firms acting as agents for the Ministry.

(*d*) FACTORIES FOR NOVEL STORES.

During the last two years of the war it became necessary to provide a means of making entirely new stores of which bulk manufacture had not before been attempted. In several instances a national factory was chosen for the purpose in preference to the placing of contracts, whose terms would have been extremely difficult to settle, while it was also considered that entire secrecy and immediate production would be easier to obtain in a Government factory. Thus the construction of a special national factory for the R.T.S. incendiary bullet was begun at Coundon in July, 1917, the management being deputed to Mr. J. F. Buckingham, who had invented another type of incendiary bullet, which had been named after him. The two Birmingham Rifle Factories were of a similar nature. Owing to the peculiar skill and experience required for rifle manufacture, no attempt was made to supplement the Royal Small Arms Factory by establishing new Government factories for this purpose. The only exception to this rule was made in the case of the newly adopted Farquhar-Hill automatic rifle, as demand was received for large numbers of this weapon in May, 1918, and it was considered that the only practicable method of supplying large numbers of so novel and complex a weapon was to arrange for a peddled scheme of components manufacture and to centralise assembly in national workshops. Before the factories had come into operation, the demand for this rifle was, however, withdrawn.

A more successful scheme for using a central assembling shop under national control had already been in operation since August, 1917, in Oxford. The Cowley works there had been equipped in the previous March for assembling parts of naval mine-sinkers, which were made under a comprehensive peddled scheme. The essence of this arrangement was a very close control over the receipt and assembling of the components in the national factory, which was managed by an agent in close touch with headquarters.

Although the manufacture of optical instruments in England was strictly limited before the war, no national factory was established in the early days of the war, considerable extensions of plant being undertaken by private firms. A great increase of demand at the end of 1917 led to an appeal from the Periscopic Prism Company to the Ministry to provide funds for new buildings at Kentish Town. It was decided in February, 1918, to take over the original factory, add the new buildings and combine them in a national factory. Three directors were appointed to manage the works for the Ministry.

Soon afterwards another Government factory for the production of photographic lenses was established at Brimsdown, near Enfield. Until early in 1918 the French had supplied lenses for the Hythe Camera Gun, but that year this resource failed, private firms in England could not meet the need, and consequently the Brimsdown factory was built. It made deliveries in July, 1918, and continued them until the Armistice.

(*e*) National Aircraft Factories.

With the exception of the very small, and chiefly experimental output of Farnborough, the Government had trusted to private firms for the adequate supply of aircraft until August, 1917, but the continually increasing demand forced the Ministry, which had become responsible for aircraft production, to recognise the necessity for national factories on a large scale instead of distributing work among numerous comparatively small contractors. It was thus intended to concentrate tuition work, which was extremely heavy in the case of aircraft production, and to obtain the advantages of large scale production already experienced in the great gun ammunition factories. Three National Aircraft Factories were designed at the outset, at Croydon, Liverpool and Manchester, the management of which was to be in the hands of experienced firms. Construction was slow in the case of all these factories. Manufacture at the Waddon Factory at Croydon began in March, 1918, and at the Heaton Chapel Factory at Manchester in April, and the first finished machine was not despatched from the Aintree Factory at Liverpool until June. In no case did the output come up to the estimates, but it must be remembered that the venture was new and launched at a time when labour difficulties were at their height, all the skilled labour in the country being already absorbed in other work.

No concurrent scheme was made to erect new national factories for aero-engine production, one of the main reasons for nationalising aircraft production being the large amount of space required. The output of engines was, however, of very grave moment at the time, and in order to ensure deliveries certain shops were nationalised. A subsidised factory at Hayes was taken over in October, 1917. The automobile works of Messrs Clement Talbot, Ltd., at Ladbroke Grove, were acquired in January, 1918, as a special provision for the repair of Rolls-Royce aero-engines, and the works of the Motor Radiator Manufacturing Company at Greet and Sudbury were nationalised at the same time. Late in the year assembling stations for American machines at Oldham were taken over with a view to general reorganisation.

Other projects for National Aircraft Factories were ultimately abandoned; but a National Balloon Factory was established in the works of a cinema firm at Finchley in January, 1918, to meet a largely increased demand.

The list of national factories established during the war is a long one, but long as it is, its most important items belong to the first two years of the war. In those years were founded the most successful of the great factories for producing explosives, to them belong the programmes of the National Shell, the National Projectile and the National Filling Factories. Minor schemes were carried out with success after the summer of 1916, but all that was swift and dramatic was not only conceived but carried through before that time.

CHAPTER III.

CONSTRUCTION AND EQUIPMENT OF THE NEW FACTORIES.

The problems presented by the construction of national factories were many and great. The buildings were needed swiftly and in large numbers; they were under several different types of management; they produced an immense variety of goods; in some the work done was largely experimental; in explosives and filling factories safety conditions had to be considered; where labour was scarce it was sometimes necessary to design townships as well as workshops. Problems of equipment also were complicated. New buildings, derelict buildings, buildings formerly used for other work had to be provided, and the national factories had no monopoly in the manufacture of munitions. Their construction and equipment was carried on simultaneously with the construction and equipment of factories in private hands, and for awhile there were serious competitive difficulties as to the allocation of labour and material.

It was no easy matter for a newly-formed Ministry to establish authoritative control over the building of national factories: the business concerns to whom this task was, for the most part, entrusted were unaccustomed to official checks and investigations, and the Ministry did not wish to curb their energies, for in the second year of the war output was far more important than economy. Further, for much of the work done there was no precedent, and as a result estimates could not be given beforehand. As time went on, supervision became closer, and finally elaborate methods for checking costs were devised; but as, with the exception of some explosives factories and the aircraft factories, schemes for the more important national factories belonged to the first two years of the war, the new methods could not in many instances be applied to initial expenditure, although they were of great value in the case of extensions, many of which were on a large scale, some involving an expenditure three or four times as great as the original estimates. For example, the first estimates for the Chilwell Filling Factory were £632,100, and the actual expenditure by March, 1918, had been £2,712,097. This increase was mainly due to continual extensions of capacity. Again, the estimate given in February, 1916, of the cost of the Georgetown Filling Factory was £264,100, but the ultimate capacity was four times as great as had been contemplated in the first instance and the cost rose to £1,368,356 by the spring of 1918. At Gretna one extension after another was made, and the first rough estimate of £2,000,000 given to the Treasury in November, 1915, showed little relation to the final cost of over £9,000,000.

I. Construction and Construction Contracts.

(*a*) CONTROL OF CONSTRUCTION.

Speed in construction and in making deliveries was the first thing asked for from the national factories. The great national factory programmes were designed to meet urgent and imperious needs. Construction, not control, was the foremost idea. The Government was prepared to entrust construction to any person, or body of persons, who seemed likely to carry it through efficiently. The main difficulty was to find them. Supervision of construction was not at first entrusted to any single body, but was left to the department responsible for the particular supplies required.

H.M. Office of Works was the outside body to which the Ministry had recourse, when national factories were first being built, for technical advice and supervision. It was called in before the passage of the Defence of the Realm (Acquisition of Land) Act, December, 1916, to assist in acquiring for the Government land needed for factory sites, but not permanently required for military purposes. Also in the summer of 1915 its services were called upon with regard to the construction and equipment of factories. Its functions with regard to the National Projectile Factories were, in August, 1915, summarised as follows :—

(1) Giving a general technical criticism of the schemes.
(2) Making a full investigation of the prices for the erection of the buildings.
(3) Arranging for contracts for the execution of the work.
(4) Placing Clerks of Works on the sites and generally supervising.

The Office of Works was further called in to assist in the construction of the Filling Factories. Mr. (later Sir Frank) Baines, the principal architect of the Office of Works, was specially deputed to assist the Ministry of Munitions, and technical officers were also provided, whose functions with regard to the National Filling Factories were outlined as follows :—

(1) To keep in close touch with the Board of Management.
(2) To expedite the work in every way they could.
(3) To act as Clerks of Works.
(4) To be the technical intermediaries between the Board of Management, the architect, the local contracting firms and the local authorities.
(5) To advise the Board of Management as required on any matter connected with the execution of the work, so as to prevent unbusinesslike arrangements being made, and generally to aim at getting the Board of Management to work on Government lines in a businesslike way, and to prevent the acceptance of prohibitive tenders or offers.
(6) To measure up the work and check the value of the work done.
(7) To certify advances to the contracting firms and to authorise all variations, omissions, additions, etc., as the work proceeded.

To Mr. Baines was entrusted the control of any technical officers sent to the various sites by the Office of Works.

A short time afterwards two appointments were made, one of which strengthened the Ministry's financial control over the construction of national factories, while the other transferred to it some of the functions recently undertaken by the Office of Works. The first appointment was that of Mr. (later Sir Hardman) Lever as Assistant Financial Secretary, in October, 1915, with specific responsibility for all important contracts involving an expenditure of £40,000 and upwards. The second appointment was that of Mr. (later Sir John) Hunter, who was made Director of Factory Construction in November, 1915. His services were secured especially with a view to the supervision of Projectile Factory construction and to hastening their erection in every possible way, but his work and that of the Factory Construction Department was considerably extended later. As far as the Projectile Factories were concerned, Mr. Hunter's appointment left little of its original functions to H.M. Office of Works, except the provision of office supplies.

The position was different with the National Filling Factories. The Office of Works was asked and consented to allow its technical assistants to continue their work on the Filling Factories, and Mr. Baines completed the work he was doing in co-operation with the officials of the Ministry concerned. The Office of Works also supplied auditors for the accounts of the Filling Factories. In some cases it was asked to undertake even more detailed work in those factories, for the National Chemical Shell Assembling Factory at Greenford, completed in February, 1917, was constructed by the Office of Works, and the last National Filling Factory, at Gainsborough, built in the winter of 1917, was also built by it.

The control of construction was slight during the first eighteen months of the war. The single policy which actuated the Ministry was that of securing output by the speediest means. The Treasury had given great financial freedom to the Ministry, and the Ministry gave similar freedom to many of the bodies concerned with factory construction. Building was well under way in many of the Filling Factories before Mr. Baines' services were called upon; ill-defined and varying methods of financial control had been instituted before Mr. Lever became Assistant Financial Secretary. It was no easy matter to impose good methods on chaotic ones, and the finance of construction was not considered satisfactory as late as October, 1917, when the Select Committee on National Expenditure complained that control over money spent on construction was not sufficiently definite.

An attempt was made by Dr. Addison, after he became Minister, to centralize the control of constructional work by the establishment of the Munitions Works Board. This Board, instituted in January, 1917, was a branch of the Finance Department. It was recognised that the various groups of factories had different needs and that no single department would find it easy to deal adequately with the technical side of all the proposed extensions; consequently, in spite

of many discussions as to the possibility of co-ordinating all construction work under one department, it was throughout largely left to the supply departments of the different sections. But the supply departments were instructed to submit all their demands to the Munitions Works Board, and it was the duty of the Board rigorously to examine such demands. Further, the Board was expected to supervise all constructional work.

It was difficult for the Munitions Works Board to assert their control over the supply departments, which had acquired a large measure of independence. The Contracts Department had been responsible for conducting all negotiations with contractors in conjunction, where necessary, with the supply departments, but it was found that in some cases the supply departments had acted without reference to the Contracts Department. In the spring of 1918 the Munitions Works Board was reconstructed with more clearly defined powers with regard to constructional works, including the consideration and approval or rejection of all proposals for capital expenditure and control of the method and cost of execution of the work. Little time remained before the end of the war to test the value of these developments, and the amount of constructional work done during the last six months was not great.

(*b*) Construction Contracts.

There were many differences in the procedure for placing building contracts, not only between factories producing different goods but between factories producing the same goods and between different builders in the same factory. The officials who were responsible for construction in the early days had great freedom and drew up different contracts according to the exigencies of the moment and the demands of those with whom they had to deal.

But the discrepancies in the contracts were not solely due to a lack of coherent policy. Some factories had to be built at great speed, and this caused the use of certain contracts which were later thought unsatisfactory, while the fact that some were built for production on comparatively well-known lines, while others were ventures into unexplored territory, would have necessitated many variations in contract even if central control had been perfect and time indefinite. The following extract from the Comptroller and Auditor-General's Report, 1916–17, illustrates these points in relation to Filling Factories :

> " In the case of all the Filling Factories the estimates put forward in the first instance were made without details of buildings proposed to be erected and without any complete information as to lay-outs. The work of construction was proceeded with in the most rapid manner possible, all considerations being subordinated to speed of construction and attainment of output. The estimates of cost put forward were known to have been made with only the most hazy ideas of what the planning of these factories was to be and with frequent alterations in design owing to changes in filling requirements and mixtures to be used. The construction

work was frequently placed in the hands of managers selected by Mr. Lloyd George and given by him an absolutely free hand to construct or make contracts for construction, *e.g.*, Chilwell to Lord Chetwynd, Hayes to Mr. A. C. Blyth, etc.; they were started at a time when our capacity for filling was ridiculously small and in circumstances which amounted to grave national emergency. The officials concerned with construction would brook no 'interference' or financial control, having in view their charter from the Minister. The estimates of February, 1916, were given when construction had only been a short time started, and the branch entrusted with the work was greatly overburdened with actual supervision of construction."

"There is little doubt that with time for consideration of plans, preparation of estimates and placing of contracts, more economical production might have been secured, but it is probable that the variation in planning has resulted in the long run in the discovery and general adoption of improvements in filling mixtures and methods of filling which could not otherwise have been secured."

The description given was not only true of Filling Factories; it presents the early position with regard to the principal Explosives Factories, and to some extent with regard to Projectile and Shell Factories also, though greater experience could be commanded in planning and building the latter.

The building agreements which gave the greatest freedom to the contractor were time and line contracts, under which the whole cost of construction was borne by the Government, and remuneration was given to the contractor by a percentage payment on the cost of material and labour.

The disadvantages of the system are obvious. Since a percentage was paid on all materials and labour employed, it encouraged rather than discouraged wasteful expenditure. Absence of estimates prevented competition from reducing costs. There was no direct incentive to speeding up labour. It was to the advantage of the contractor to take on more workers rather than to get good work from those he had. Many instances of inefficiency in labour arrangements were quoted in this connection. It was said that "after allowing for the increased rates of wages it had been proved that the productivity of labour at Gretna was something like 40 per cent. of pre-war productivity." In another Explosives Factory at a time when building labour was exceedingly scarce, 50 per cent. of the numerous employees engaged under this system were dismissed without seriously affecting the rate of construction.

Rates of wages were not left to the contractors; they were fixed by the Ministry or Board of Trade arbitrators. But it was in the employment of an unnecessarily large number of workers that time and line contractors often did a grave disservice to the community. The expenditure of an unduly great sum on labour was more mischievous if spread over many than if concentrated on few workers, since it held men back from other work of national importance. Hence determination

of the rates of wages was of little use unless accompanied by close supervision of the number of workers employed and the amount of their output. For this purpose the Finance Department appointed special time-keepers in the various factories. They kept a close watch on the work done, and in consequence discipline was strengthened.

Checks on materials were kept by the appointment of a technical officer of the Department of Explosives Supply to examine all orders, while a Government inspector took account of the material when it reached the factory, and the contractor was instructed to certify the accounts for materials before passing them to the officers of the construction managers.

Much of the construction in the largest Explosives Factories, Oldbury, Gretna, Queensferry, Avonmouth, and in many smaller ones, was carried on under these contracts. They had been common in explosives factories before the war. It was said that :—"the fact that it is impossible to estimate in advance the cost of the work prevents the arrangement of contractors' profit on the basis of a fee instead of a percentage." Mr. Quinan maintained that for work so new no estimates could be given except at a price unnecessarily high, because contractors would not undertake the work unless they were safeguarded by the promise of a reward great enough to provide for all contingencies.

From this point of view it was agreed that time and line contracts were economical. In illustration of this the Projectile Factory at Hackney Marshes may be mentioned. There was some confusion in the original contract for this factory, which was "partly on a lump sum basis, partly on a schedule of rates, and partly on a cost plus percentage basis." Because of the objections to paying in different ways on the same contract it was decided to have the work carried out entirely on a cost and percentage basis, with the result that the final cost was less than it would have been under the lump sum contract.

If for unknown work estimates were insisted on, contractors with no precedent to guide them would ask for sums far beyond the probable cost, lest, the probable cost being exceeded, they should find themselves losing heavily. Mr. Quinan himself absolutely refused to give any estimates of the construction costs at Gretna till the work was well advanced, but in place of estimates he gave an assurance that the cost of the product would not be more than half the price paid for American imports.

Another advantage claimed for time and line contracts was that, where they prevailed, work could be done more swiftly "without the delay which the preparation of complete plans and specifications and the obtaining of tenders would involve." In the construction of large factories the work of designing was so lengthy that the buildings were often complete before detailed plans were ready. To wait for them would have retarded matters to an intolerable extent when production was urgently needed. Further, when, as at Gretna, State manufacture meant a great saving in expense, delay might be as uneconomical as disastrous.

It was generally acknowledged that nothing but great urgency could justify the use of these contracts. They made extravagance profitable to the contractor; and the plan of first making contracts which encouraged wastefulness in material and labour, when both were scarce, and then appointing officials to discourage the wastefulness was, to say the least, unsatisfactory. Yet, for the reasons given earlier, the time and line contract was used to the end of the war in certain factories as being the only one under which firms could be induced to embark on the construction of factories of a new type. As far as possible this type of contract was avoided, not only with regard to any given factory, but in any part of the work in which this peculiar advantage did not apply. For instance, at Gretna time and line contracts were used for the factory and not for the township, since the building of increased hut accommodation for the workers was a matter of repetition work for which the expense could be foretold.

Time and line and cost and percentage contracts were common in the construction of Filling, as in that of Explosives, Factories, and for the same reasons. It is possible that they led to more unnecessary expenditure, for, as has already been indicated, the assertion of financial control over the Filling Factories was peculiarly slow and difficult. Moreover, in the construction of the largest Explosives Factories a department of the Ministry dealt directly with the building contractors. Mr. Quinan, for instance, was himself responsible for the contracts at Gretna and Queensferry. But the largest Filling Factories were controlled by Boards of Management or managing directors, and the terms of the original contracts were not closely supervised by any central department of the Ministry.

There was not generally the same necessity for these contracts in the construction of Projectile Factories, but they were not unknown. The case of Hackney has been mentioned. Time and line contracts were also originally entered into at Birtley, but ultimately the work was taken out of the hands of the contractor and completed under the direct supervision of a representative of the Ministry. The Director of Factory Construction, reporting in January, 1917, to the Assistant Financial Secretary on extensions in Projectile Factories undertaken under cost and percentage contracts, wrote as follows :—

> "Part of the work to be done is the reconstruction and extension of existing work, which involves its being done as and when possible, so as not to interfere with the running of the existing plant. This class of work cannot be carried out on any other basis unless at prohibitive cost."

And again :—

> "The reasons for adopting cost and percentage contracts for all general contractors' work required are, first, the fact that in practically every case the work is largely jobbing work carried out amongst the running plant of the existing steelworks and, second, the fact that there was no time to prepare formal drawings and quantities, even if it had been possible to do so."

He pointed out that similar difficulties were experienced in the case of assisted contracts, *e.g.*, in the case of certain steelworks extensions, and finally summarised the reasons for the adoption of cost and percentage contracts :—

> " (1) Cases where the work to be done involved lump sum, schedule of rates and cost and percentage payments and the consequent difficulty in checking materials and labour under these different heads.
>
> " (2) Cases where the managing firms had already entered into such contracts before the Ministry had an organisation dealing with such questions.
>
> " (3) Cases when the preparations of complete plans, specifications and schedule of quantities and the taking of competitive tenders from contractors would have involved such delay in the completion of the works that the value of the scheme would have been seriously affected."

The percentage rates at which these contracts were made fell when both parties to the contract saw what large returns they gave. Hence rates for late were lower than those for early contracts. For instance, the original fees agreed on in February, 1915, at Oldbury, the first great national factory built during the war, were 15 per cent. on wages until 31 August, 1915, and 10 per cent. afterwards, and in addition the responsible firm were to retain all discount on material purchased. These terms were intended mainly to compensate the firm for turning their attention to an entirely new industry, and later contracts were made on similar lines with experienced explosives makers, and in less urgent circumstances, at rates such as 6 per cent. on wages and $1\frac{1}{4}$ per cent. on materials.

Some of the early contractors also consented to a reduction in the terms of the original contract. This was the case at Birtley, one of the few National Projectile Factories to be built under these contracts. Since there were no estimates of the probable cost of the factories under these contracts the remuneration was, like the total cost, outside the region of prophecy, and so often proved to be altogether beyond it, that, in view of fresh contracts, the firms concerned were willing to revise the terms of the old ones.

The disadvantages of time and line contracts were sometimes mitigated by the purchase of process plant by the Ministry. Both at Gretna and Queensferry it was supplied by the Ministry, and consequently no percentage on its price was paid to the contractors. This affected a considerable saving, since the plant represented about half the total outlay. At Gretna, for example, the total payments to the numerous time and line contractors engaged were estimated in April, 1917, at £3,750,000 ; on this the contractors' commission would amount to about £200,000, or an average of 5·3 per cent. The firms had, in fact, done not much less work than would have fallen upon them had they also had to purchase the process plant ; yet they received only 2·5 per cent. on the total cost of the factory, then estimated at £8,000,000.

The Ministry were throughout fully alive to the advantages of incurring known rather than unknown expenditure. Whenever they could, therefore, without unduly delaying construction, they encouraged the use of lump sum and priced schedule contracts, since under these contracts a definite sum was named as the one at which the work would be completed. Payments were made to the contractor on account, from time to time, on the certificate of architects, engineers or other officials appointed by the Ministry, showing that work exceeding the proposed payment in value had been satisfactorily executed. Final payments were made when final certificates of completion had been received from such officials. The contractors sometimes received a supervision fee in addition to the lump sum, but more often a percentage on it. For instance, most of the management firms which undertook the designing and construction of the Projectile Factories had lump sum contracts with the Ministry, whereby they received in addition to the sum specified—

4 per cent. on the first £250,000.
3 per cent. on the next £250,000.
2 per cent. on the next £250,000.
1 per cent. on any further expenditure.

The priced schedule contract varied from the lump sum contract only in that it entailed the engagement of quantity surveyors to verify contracts and prices.

Lump sum or priced scheduled contracts were made in the first instance for all the Projectile Factories except Birtley and Hackney Marshes, though, as has been seen, other contracts were sometimes used for extensions. Several of the Filling Factories were constructed under them. They were made for a comparatively small number of the Explosives Factories; it is interesting to notice that the three agency factories, Lytham, Bradley and Greetland, designed early in 1917 for the manufacture of picric, were constructed under lump sum contracts, though for Avonmouth, built under the direct supervision of the Department for the same purpose a short time before, a time and line contract had been made.

II. Lay-out and Equipment.

(*a*) METHODS OF CONTROL.

The early inception of the great explosives factories, the lack of expert knowledge outside the Ministry, the special problems of safety conditions and large scale production, gave the Government a more complete control over their lay-out and equipment than was common elsewhere.

The drawings for the most important of these factories were prepared in a Government office; even those for Oldbury, which was under agency management, were carefully prepared under the direct supervision of Mr. K. B. Quinan. In many of the smaller factories the design was left to contractors, indeed so many of them were begun as private ventures that the Government had no say in the matter until it took them over, when it was often faced by problems of reconstruction and re-equipment.

For the design of the Filling Factories also there was a considerable measure of early central control. The lay-out of the factories for assembling and filling quick-firing ammunition was prepared at headquarters and the work of designing factories for filling large natures of shell, with the exception of Chilwell, for which Lord Chetwynd was solely responsible, was entrusted to the consulting engineer of the Gun Ammunition Filling Department. The designing of factories for filling small natures of shell was, however, left for the most part to the managing director or to the firms acting as agents.

The management firms which undertook the construction of the National Projectile Factories were left to design them according to such methods as their experience suggested, but the designs had to be submitted to the Ministry for approval. The fact that the firms had experience and that considerations of safety were not especially prominent made it unnecessary for the Government to assume so much responsibility.

As for the National Shell Factories, under Boards of Management, the question of equipment was important, but there was no question of design. These works were housed in already existing buildings which had to be adapted to new uses.

The control of equipment was a slow growth, though, as has been seen, the Government in very early days supplied the process plant for Gretna and Queensferry, and the Ministry took a great part of the responsibility for the provision of plant for the Filling Factories. The firms managing National Projectile Factories were at first authorised to buy their own plant. Orders had however, to be submitted to the Ministry, who settled any question of allocation, and before long a more stringent control was imposed, certificates from the Machine Tool Department being required before orders could be confirmed. In the case of National Shell Factories, the Boards of Management were empowered to hire or purchase machinery available in the district. Many difficulties arose later, especially in the National Shell Factories, from faulty or worn equipment, efficiency having been in the first instance sacrificed to speed, and as a result individual factories were unable to yield a large output. This was rectified in the long run by closer control being instituted over equipment, and much of the plant acquired by the Boards of Management was discarded in favour of plant supplied by the Ministry.

(*b*) Old and New Designs.

The erection of the national factories took place at a time when scientific management was coming to the fore and when the cost of labour was sufficiently high to encourage the discovery and use of labour-saving devices. They gave scope for experiments, and the circumstances in which they were constructed greatly increased the importance of methods of economising labour and material. To secure the speediest output possible transit facilities within the factory were of the greatest importance, and it may be noticed here that it was not easy to combine perfect transit with perfect safety arrangements. The method of building in units so that any explosion should affect

a relatively small portion of the works was not readily compatible with methods of passing material from one process to the next. For example, at the largest filling factory at Chilwell the internal transport arrangements were extremely efficient, material and plant passed with the greatest celerity from one part of the works to the next. The factory was built with astonishing speed, and made early, good and economical deliveries. But the factory was not subdivided as were similar ones, into small units. Close connections and complete isolation could not be secured simultaneously, consequently the risks of explosion at Chilwell were particularly great, and another factory was designed to supply the deficiency, should an explosion occur.

In addition to considerations of safety, speed and economy, there were a number of problems arising from the employment of women. Not only was labour scarce, but much of the labour available was that of persons new to the work, and not so strong as that of the men who would ordinarily have been employed. This affected the whole lay-out of factories. The best and newest were designed so that little lifting was needed. Internal rails were constructed, not only to pass as near to the product as possible, so that there was no distance to traverse between the place at which the product was made and that at which it was loaded, but also at such a level that no raising of the product was necessary. These methods would have been advantageous when men were employed; the employment of women made them essential.

Improvements in design came with experience. Some of the factories built in the first months of the war suffered to the end, both from haste in construction and from defective lay-out, while buildings which were "taken over" were often congested and could only by very careful planning be made fit for the work to which they were put.

Oldbury—the first great National Explosives Factory—was an instance of one which, though carefully designed, was planned without any experience of what could be done on so large a scale. It was built very rapidly because of the urgent need for its products, and before the process to be used had ever been attempted on a manufacturing scale. Other factories surpassed it towards the end of the war in efficiency and in lowness of costs, and this was largely attributed to its early inception and to the swiftness with which it was built.

Greater difficulties were experienced at Litherland, which was begun earlier than Oldbury, in the autumn of 1914, but nationalised later, in the spring of 1916. This factory, which had originally been intended to yield the whole of the necessary supply of T.N.T. for filling small natures of shell, was started in such haste that output was seriously delayed, so ill-balanced was the lay-out, so inadequate the supply of steam, so unsatisfactory the plant. Oldbury was sufficiently well laid out greatly to exceed its estimated capacity, but it was but slowly that Litherland attained its full output, and when it did it had difficulty in maintaining it.

In contrast to these Gretna stands out as an example of a well-designed factory built comparatively slowly for a manufacturing operation which had been in practice for many years. Full time was taken for the construction, so that the best plans might be

developed and the most up-to-date methods of scientific management used. Progress from raw material to finished product for a distance of nine miles was carefully arranged. The factory was divided into areas; in the first stood the glycerine distillery, and the acids, nitro-cellulose and nitro-glycerine sections; in the second the paste sent from the first was made into cordite; in the third were magazines for the finished cordite. The second area, in which the cordite was made, contained units widely dispersed for the sake of safety, and close to it was placed a section for the supply of ether-alcohol to which the solvent recovered from the cordite was sent for distillation. The central electric power station was placed between the first two areas, and the water intake and pumping station was a short distance from the third. Townships, containing not only housing accommodation, but churches, schools, public halls, post offices and shops, were conveniently placed in the neighbourhood of the various sections, so that time should not be wasted by the workers in going to and fro.

Greetland, one of the three factories designed in 1917 for the production of picric, was another example of a well-planned factory. The site was well chosen, lying between the main road from Halifax to Huddersfield on the one side, and the Lancashire and Yorkshire Railway on the other. The order of processes was scientifically managed and the site being below the level of the railway, sulphuric acid could be run by gravity from tank wagons to storage boilers and thence to other parts of the factory. It was chiefly because of the excellence of the lay-out that economy and efficiency were carried to such a high pitch at Greetland; it could, however, not be said that the work was better done there than elsewhere solely because those who planned it learned from the experience of their predecessors, for the contemporary picric factories at Bradley and Lytham were less successful.

As war demands grew, the possibility of expansion became of great importance. Many of the new factories were designed with a view to a possible increase in capacity, many of the old ones suffered from congestion. For instance, Litherland, placed at the disposal of the Government early in the war and converted from the production of aniline to that of first M.N.T. and later T.N.T., suffered from overcrowding. The factory had not been built for the purpose to which it was put, it was not easy to increase the capacity, risk from fire and explosion was great, and the factory was never a very satisfactory one. On the other hand, the Explosives Factory at Ellesmere Port was deliberately planned so that the building should be uniformly capable of housing additional plant. In some other factories the lay-out was designed so that units of production could be multiplied.

The National Shell Factories for the most part suffered from congestion and all the disadvantages of "converted" premises. Certain Shell Factories, however, such as Dundee, proved what could be done when the lay-out was good. The orders received by this factory were peculiarly erratic, but the factory was turned from making one type of shell to another, in some cases, without any stoppage of the day

and night shift. Output maintained a high level, but cost of production was low and the general success of the factory must be attributed to its careful planning.

Difficulties with regard to plant and equipment arose in many of the early factories, and more especially in the Shell Factories, for which the Boards of Management secured whatever plant was available in the area. In some few cases they were fortunate. For the Dundee factory the local Board secured the use of a prize cargo of American engine lathes, intended for Germany. But the local hire or purchase of second-hand machinery led to many difficulties. The Huddersfield Shell Factory, for instance, was ill-equipped and had to be provided with new machinery before it attained any satisfactory output.

In some cases the proper equipment of a factory was hampered by an entire lack of former experience. For instance, the Chittening Filling Factory, designed for charging shell with mustard gas manufactured at Avonmouth, was equipped with an extemporised and unsatisfactory plant, pending the development of knowledge and experience. These conditions increased the number of casualties, particularly among the fitters. Alterations to equipment were made as experience was gained; but the need for immediate output was considered to be so urgent that it was necessary to accept casualties in the factory as the price to be paid for maintaining the equipment and morale of the army in the field.

But for most of the new factories, especially those designed on a large scale, like the great Explosives Factories and the best of the Filling Factories, plant was secured which matched the lay-out. They were splendidly equipped from the first, and those who planned their equipment were never content with it as it stood, but were constantly on the watch for labour-saving devices and constantly making experiments which called for the instalment of new plant which should be more effective than the old.

This was especially the case with the Filling Factories. Chilwell from the first had plant for speeding up processes, and developed the methods which enabled filling directly into the heavy shell instead of filling with amatol blocks to be made universal in the Filling Factories. Block filling increased the difficulties of detonation and also wasted labour, since it involved the use of shells with removable heads or base-adapters. It was accordingly retained in smaller natures only and not applied to the heavy shell, for which a satisfactory means of detonating the block-filled charge had not been found.

In July, 1916, experiments in hot filling were made at Georgetown and proved exceedingly successful. One great advantage of the new process was that it enabled use to be made of existing buildings in filling with 80/20 instead of 40/60 or 50/50 amatol. It was also adopted in October, 1917, for the whole of the American shell-filling programme.

Experimental work in screw-stemming was done first at Morecambe and later at Liverpool, and in the spring of 1917 screw-stemming machines for cold amatol were installed at Chilwell and Liverpool. Experiments in screw-stemming with hot amatol also proved successful, first with a vertical, but later with a horizontal machine, which proved

even more effective. The adoption of these machines represented an enormous saving of labour over the previous methods of hand-stemming. They were restricted to gun ammunition filling, since the filling of trench warfare ammunition was subject to constant changes.

The work of the Filling Factories which were engaged upon components was ultimately highly standardised. The establishment of a standard production unit at Perivale, where experiments were carried out under ideal conditions, did much toward setting a standard to all other filling factories in this respect.

In the shell-making factories standardisation was achieved after a good deal of effort. They were also especially notable for the number of labour-saving devices introduced so that work on heavy material might be brought within the scope of women. The use of overhead cranes, rolling bands, automatic chucks, became common. Crane equipment was the subject of special attention. One instance of this may be given from a National Projectile Factory, in which 6 in. and 9·2 in. shells were handled. It was recognised that light floor travelling cranes were needed in addition to the usual overhead travelling cranes, and consequently a light hammerhead type of crane was designed which fed the machines with single shells lifted from the floor, from benches or from tubs. They travelled the whole length of the bay, supplied with power from electrical feeders laid in underground conduits. Hand jib cranes were also installed for feeding machines used for quick operation on 6 in. shells. These hoisted the shell from a neighbouring bench or trestle arranged at the level of the lathe spindles, the bench or trestle having been filled by the hammerhead floor or overhead cranes. All the cranes—overhead, floor, hand, jib—were managed by girls, with the exception of one heavy overhead crane used for lifting exceptionally great weights.

The cotton waste mills were actually taken over by the Government so that new methods should be introduced. Experimental work was done in them which led to the instalment of improved plant. The Greenfield Mill, for example, was at first used for experimental work, then closed for six months while certain manufacturing trials were carried out by Nobel's Explosives Company. It was then restaffed and newly equipped. As a result there was a very great increase in output. The quality of the product was improved, while the financial effects of the change were highly satisfactory.

Many experiments were made in national factories for simplifying processes and so, by saving the number of stages through which the material went, economising time and labour. Direct filling in the Filling Factories has already been mentioned. Another instance may be cited from the Explosives Factory at Langwith, where in August, 1917, a new process was discovered for certain parts of the manufacture of ammonium perchlorate by which the number of stages was reduced.

The need for economy in labour was evident in very early days; it was followed by an equally great need for economy in materials. The national factories were naturally used as centres for experiments in economy. When the first of the engineering factories were built cost had been disregarded, speed and output being the chief object of

all munition production. Later it was recognised that supplies must not only be adequate for the moment but that they must hold out. The danger of exhausting resources obtained an importance equal to that of the previous need for utilising them to the full. In the case of the first High Explosive Factories, on the other hand, national plant had been erected primarily with a view to economising the basic raw material, since it had been a fixed policy to manufacture as much T.N.T. as could be made for Great Britain and her Allies.

As far as metals were concerned economy was achieved rather by using every scrap of material, than by employing substitutes, though the latter were introduced to some extent to replace aluminium, brass and copper. But both with these and with steel the costing system and the methods devised for following the material from its entry into the factory to its exit, practised first in the national factories and then applied elsewhere, gave the most important results.

Further, since constant changes had to be made in the type of goods manufactured according to the demands of the War Office, the available supplies of steel had to be allocated carefully according to the most pressing needs of the moment. The national shell-making factories were the scene of constant swift readjustment in manufacture; they were continually called on to make first lighter and then heavier shell, and then lighter shell again, and sometimes were turned from shell-making to gun repairing.[1] The existence of factories under Government control which could so immediately be turned from one type of production to another made the task of allocating raw material much easier.

Great economy of material was achieved in the National Box Factories, as in the Shell Factories, by making use of all available material, in whatever form it came. Timber returned by private contractors as unsuitable for their particular work and material obtained from salvaged boxes or brought into the country with foreign supplies were converted into packing cases for munitions. The shortage of wood was a very serious problem: its bulk made it difficult to import when tonnage was scarce, and home supplies were extremely limited.

In the spring of 1917 the Ministry established a centralised organisation for the sale of by-products from the national wood distillation factories, and the initiation of the later wood distillation factories for making use of the waste wood from felling operations carried on by the Timber Supply Department shows how much stress was being laid on economy and how national factories might be used for the purpose. Modern scientific methods were carried very far in all the wood distillation factories, and in the largest of them the value of the by-products more than covered the cost of the acetate of lime, which was the chief product for which they were founded.

Economy both of labour and material was also encouraged by clauses in contracts which gave a bonus on economical working. Such clauses became popular with the Ministry as the need for economy grew, and were introduced as often as possible in the last years of the war. They were, for example, included in the agreements with the firms managing Government Cartridge Factories.

[1] See above, p. 54.

III. Progress of Construction.

While labour and material for the making of goods grew scarce, material and labour for construction also became scanty. The allocation of constructional steel was carefully considered, and it was always a question whether labour employed in making goods could be diverted to the building of more factories.

As has been seen,[1] though extensions were numerous after the first two years of the war, the number of new factories decreased, and there were many refusals on the part of the Ministry to permit further extensions of existing factories. Shipping accommodation became increasingly scarce, so that it was more and more important to use imports only for the most vital purposes; new demands for steel and iron came with the growing use of aircraft, with the submarine campaign and the development of tank manufacture; builders, not easily replaced by the employment of unskilled and female workers, seemed to become the rarest of all industrial workers. All these things gave pause to new building schemes and concentrated attention on the methods already described whereby the capacity of existing works was increased.

Where new factories were built and extensions made the work of construction tended to be slow towards the end of the war. Countless instances can be given of this. The construction of the Explosives Factory at Ellesmere Port, begun in March, 1916, was retarded by shortage of labour. Later, in June, 1918, when it was decided that alterations should be made in the factory so that it might be used for the production of poison gas, labour was so scarce that it became necessary to employ soldiers, both for construction and process work.

It was, in fact, found necessary towards the end of the war, when construction was needed and needed speedily, to devise new methods of building which should both economise labour and use material which was not in demand. For instance, the Burton Machine Gun Factory was built of thick steel frames, part plates, part boards, with slate roofs. Even so, it was not ready for use until after the Armistice. Buildings could not be erected rapidly except by departing from ordinary methods. They were undertaken only under great necessity, and to the shortage of labour and material must be attributed the fact that several factories and extensions designed some time before the end of the war were not in working order before the need for them was over.

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[1] Chapter II.

CHAPTER IV.

FACTORY MANAGEMENT.

When it was decided that national factories should be established, the problem of their management was among the most difficult the Government had to solve. It could only be solved by the use of diverse methods. Some of the factories were built on an unprecedented scale. Many were for the production of goods in the making of which no one had any experience. Engineering firms had knowledge of methods of management applicable to shell production, even if they had none of the actual manufacture of shells. But few firms had any knowledge of high explosives. With some of the new explosives everything was experimental. The Government could not find expert knowledge for the control of these factories, it could only look for managing ability. Hence it was that while the Shell and Projectile Factories were placed as a rule under the management of some expert agency, the control of the Explosives Factories was more often undertaken directly by the Government.

Even where engineering was concerned it was not easy to find enough experts. One method used in 1915 was the formation of the local boards, by means of which engineering experts could pool their knowledge and control great National Shell Factories while carrying on their ordinary business. As the work of the Ministry of Munitions grew, engineers were drawn in ever-increasing numbers to headquarters, where their advice was required on matters of administrative policy. Consequently fewer were left to guide the multiplying activities of factories which were growing rapidly in size and number. Dilution of management became as important as dilution of labour. Heads of engineering firms could only meet the pressure put on them by delegating minor responsibilities and concentrating on great ones. Firms which had hitherto managed one factory managed two or more.

No single method of management could have met the need. The willingness shown by the Government to abandon one method for another was essential to the success of such experimental undertakings. By variety of control and elasticity of method it was possible to discover new managing ability and to make use of all available expert knowledge and of every ounce of patriotic enthusiasm, which led business men to offer their services freely.

I. Types of Agency Management.

As the Government had sought in the first instance to meet the need for munitions by the agency of existing armament firms, so it tried to induce existing firms to undertake the management of the new factories. But the first factories to be acquired or built for the State had to do with the manufacture of high explosives, of which, as has been said, few firms had any experience. As a result, though many

attempts were made to get these factories managed by some outside agency, the Government was often forced into taking them under direct control. Rainham, the first factory to be acquired by the Government, was commandeered for the purification of T.N.T. in November, 1914, under the Defence of the Realm (Consolidation) Act. It was placed under the control of an agency, but this proving unsatisfactory it was transferred to the direct control of the State in May, 1915. Oldbury, the first great national factory to be built for the manufacture of T.N.T., was managed by Messrs. Chance and Hunt, a well-known firm of acid makers. The final contract with this company was settled at the end of April, 1915, though work upon the site had actually begun in January. In this case the method justified itself. The works were erected at an amazing speed, some T.N.T. being manufactured in May and full output being reached in November, 1915. When the Ministry of Munitions took over the work of the Explosives Branch of the War Office, it acquired possession of Oldbury, and Messrs. Chance and Hunt continued to manage the factory for the Ministry on an agency basis.

After the formation of the Ministry, control by means of agencies became common in the Explosives Factories, almost universal in the Projectile Factories, and was resorted to in all the Government Cartridge Factories and in the chief Aircraft Factories. The need for high explosives was so urgent and much of the work so experimental that no definite policy was formulated as to the management of factories for their production. The decision as to whether any new factory should be managed directly or by an agency, was mainly determined by whether a firm could be found competent to deal with it.

Different methods were tried according to the exigencies of the case. Several of these factories, *e.g.*, Litherland, West Gorton and Sutton Oak, were taken over from the firms which were managing them, because of their delay in making deliveries. The decision as to control in the case of the enormous Propellant Factories, such as the guncotton section at Queensferry and the great cordite factory at Gretna, was the result of the system of planning and construction. These were undertaken by the expert staff of the Department, which had been drawn mostly from South Africa. They necessarily supervised the factories during the initial stages of operation and naturally maintained control throughout the war. One or two early attempts to transfer the factories constructed by the Department to operation by agents or contractors had met with failure. Pembrey was the only large cordite factory worked on an agency basis, by Nobel's Explosives Company, and the same firm acted as agents in constructing and operating Irvine for the manufacture of nitro-cellulose powder, in regard to which they had unique facilities.

The Projectile Factories were managed on behalf of the Ministry by big shell firms, with few exceptions. In the case of the shell-making factories the policy was clear. Factories for producing the smaller natures of shell were to be managed by local Boards; Projectile Factories for making the larger natures by private firms. The distinction gave rise to some difficulties, but it was made with the

object of utilising all resources. The National Projectile Factory at Birtley was removed from the management of Messrs. Armstrong, Whitworth early in February, 1916, because of peculiar circumstances. The firm had undertaken in July, 1915, to erect two factories, one for the production of shell, the other for that of cartridge cases. In August, 1915, Belgian labour was introduced, and in the following February a contract was signed between the British and Belgian Governments by which the British Government undertook to pay all expenses, and the Belgian Government to manage the factory and provide labour. The Belgian Government wished to work directly with the British Government. Consequently, Messrs. Armstrong, Whitworth gave up the management of the National Projectile Factory, though they completed the building of it, and continued to operate the neighbouring cartridge case factory on a contract basis. The only other Projectile Factories not worked on the agency basis were the three at Leeds which were under the management of the local Board of Management, and three contractors' factories in the London area, which were taken over as National Projectile Factories in 1918.

The three Government Cartridge Factories were also erected by private firms, with special arrangements for their management. The firms purchased the necessary land and erected and equipped the factories at the expense of the Ministry ; they controlled the factories. but bought their materials from or through the Ministry, which advanced money for their purchase.

Five only of the Filling Factories were managed by private firms. In the case of the Morecambe Filling Factory the management was placed in the hands of Messrs. Vickers, who had been entrusted with that of the National Projectile Factory at Lancaster. The Morecambe Factory was near enough to Lancaster to make it easy and inexpensive to have the empty shell conveyed from the National Projectile Factory for filling purposes. The Coventry Fuse Filling Factory was placed under the charge of Messrs. White and Poppé, who were acting as sub-contractors to a great armament firm and owned an engineering works at Coventry, which was thought to be a good centre for a filling factory. Abbey Wood was managed by the King's Norton Metal Company, which had considerable experience in the type of work to be done. Nobel's Explosives Company was entrusted with the erection and management of a Filling Factory at Cardonald. In January, 1917, the Ministry took over the loading factory at Pembrey, which had been erected and equipped by the Explosives Loading Company, and appointed the company as agents for the administration of the factory as a natural corollary to the nationalisation of the Pembrey T.N.T. Factory. As in the case of the Explosives Factories the Government tried to find firms which because of their experience and the location of their own works were competent to carry out the work. This was an easier matter in the case of component filling and the handling of lesser natures than with the filling of heavy shells. And so many shell-filling factories were needed that private firms could only be found to control a minority of them. The others were controlled directly by the Ministry or by local Boards.

Among the Trench Warfare Filling Factories, Denaby alone was permanently managed by an agency. Attempts were made to control several others by this method, but the negotiations broke down and the Ministry took over the factory management. In the Denaby factory the control of the central organisation was closer than in most factories run on the agency basis, since the Ministry had power to dismiss labour and vary the rates of wages.

In the National Gauge Factories the position was reversed. Except in the case of the Fairfax Gauge Factory, the Government did not establish new works. Consequently instead of the Government's placing its own factories under the partial control of private firms, the firms were placing their factories under the partial or entire control of the Government. There was little similarity in the terms of agreement between the Government and the various firms, but for the most part the firms were more independent of the Ministry than was usual in national factories worked on an agency basis.

In August, 1917, the method of management by agency was adopted for the new National Aircraft Factories. The equipment and management of most of these factories was entrusted to private firms, who carried on the work under the control of the Aircraft Production Department until July, 1918.

Roughly speaking, about one-third of the national factories were run during the early days of the war by private firms on an agency basis. The proportion would have been larger but for the lack of technical knowledge where Explosives and Filling Factories were concerned. The Ministry was reluctant to assume unnecessary responsibility for management, and threw it on to experienced firms whenever they were prepared to undertake it.

II. Management by Local Boards.

(*a*) Constitution of Boards of Management.

Local organisations for the production of munitions had sprung into being even before the inception of the Ministry itself. The initiative and patriotic fervour shown by these local bodies led to various schemes of geographical co-ordination of output and local control. Sir Percy Girouard, after visiting several industrial centres in April, 1915, came to the conclusion that the local committees might be utilised for an important National Shell Factory experiment. He was convinced by that time that new Shell Factories were essential. Early in May, 1915, the general outlines of a scheme for a factory at Leeds to be managed by a local Management Board was approved by the Munitions of War Committee and was subsequently used as a model for all the National Shell Factories. It had great and obvious advantages. It provided expert management combined with an exhaustive knowledge of local resources and provided it freely. The Government, which appointed the members of the actual Boards of Management from the local committees' nominees, did not often appoint more than five members, as the committees spontaneously formed in different areas were too large to conduct executive work with the necessary swiftness.

(*b*) Relations between Boards of Management and the Ministry of Munitions.

As has been seen, local committees came to life before the Ministry of Munitions. No strong scheme of central control or of general co-ordination existed when the Leeds Board was asked to take over the management of a National Shell Factory. As a result the participation of the Government in the control was slight. Its sanction was required for action involving questions of compensation, and for new extensions or buildings. It was to be the owner or lessor of all machinery and was to arrange for the ultimate disposal of the machinery, plant and buildings. Auditors were to be appointed by and be responsible to the Government. Equipment was to be carried out subject to the general control of the Government. Apart from these provisions, the arrangement was that the Government should make itself useful to the Board, by bearing the costs, by supplying technical advice, by securing machinery for the use of the Board from recalcitrant owners through the use of the Defence of the Realm Act.

Early agreements made with the Boards of Management were framed on much the same lines, leaving the Boards almost completely autonomous. The position of the Boards was complicated by the fact that as members also of the local committee, they were not concerned solely with national factories but with the working out of important co-operative schemes of production in their respective districts. In some instances these schemes, rather than the efficient management of the factory, were the chief concern of the Boards.

From time to time the powers of the Boards were diminished by the increase of those of the Ministry. The Ministry, bent upon speedy output as well as on the reduction of costs, gradually extended its control. The Superintending Engineers were able to suggest technical improvements which were insisted on by the Ministry. The power of the Ministry was increased by the appointment of the D.A.O. Executive Committee in May, 1916—"to control the administration of the National Shell Factories and of other schemes administered by Boards of Management."

In view of the diversity of the results attained it was thought advisable to create machinery for disbanding the Boards, if necessary. Hence the D.A.O. Executive Committee was empowered to receive reports and call for investigations in the Shell Factories, and to refer to the Ministry any case in which in the interests of efficiency it seemed desirable to disband the Board or change the personnel. In the case of the Metropolitan Munitions Committee the Ministry exercised its power of removing the administrative powers of the Board. This involved the transference to the Ministry of the control of the two national factories, Ailsa Craig and College Park, which were thenceforward administered by the Department responsible for National Projectile Factories.

The powers of the Boards certainly diminished as those of the Ministry grew, but what they lost in power they gained in efficiency, as they were drawn into the great system of which the Ministry was the centre. They acquired knowledge of trade secrets, as the Ministry

insisted that all knowledge about the making of munitions should be used for the utmost increase of production and not for private aggrandisement. They lost the disadvantages of competitive methods and prices as they came more closely into touch with the Ministry and as the Ministry acquired stricter control over raw material and plant which it distributed to agencies likely to make the best use of them. The Boards could not bid against each other for labour or material, while the Ministry was determining the wages of the one and the allocation of the other.

The Leeds "Shell" Factories fell under the management of the local Board. The Leeds factories had, owing to the early beginning and great activities of the Leeds Committee, come under the control of the local Board of Management. In July, 1916, the control of the two factories, Newlay and Hunslet, which were producing heavy shell, was given to the National Projectile Factory Committee, though the powers given to this committee were not to interfere "with the co-operative work of the Board of Management, nor any question affecting the Board as such." In 1917, when one factory at Leeds turned over to gun repair and manufacture, the whole group of engineering factories within the Leeds area was placed under the administration of the Gun Manufacture Department in order to avoid dual control.

It has already been seen that many different methods were employed with regard to the management of Filling Factories. As in the case of the National Shell Factories local Boards were responsible for the erection and control of five of these—Leeds, Liverpool, Perivale, Georgetown and Gloucester. With the exception of Perivale, these factories were originally designed for filling and assembling quick-firing ammunition and for filling B.L. cartridges with propellants. The factory at Perivale was of a different type, and intended for the filling of fuses, gaines and other minor components. The control of the operative side of this factory was transferred to the Ministry in June, 1916, although the Metropolitan Munitions Committee, which had arranged for the erection of the buildings, retained the responsibility for construction and equipment. At Leeds, Liverpool, and Georgetown, the original schemes for filling and assembling quick-firing ammunition were extended, early in 1916, to include factories for filling heavy shell under the same Boards of Management.

It was not easy for the local committees to find men with the technical experience needed for the direction of Filling Factories. They could draw on a large body of engineering experts, but few had any knowledge of the exceptional class of work to be done in Filling Factories. It involved the erection of buildings which should guard against the risk of explosion and of damage done by explosion. Adventurousness was needed, since such factories had never before been built on so large a scale. Caution was essential, since the lives of thousands of workers were at stake. When it is remembered that the services of the members of these Boards were given freely and that the work took up the greater part of their time, it seems remarkable that any were

found to undertake so arduous a task. They constructed their factories speedily and produced large and important outputs. As time went on it was possible for several of the Boards to withdraw from any but an advisory capacity, while the Department's control over technique and finance was strengthened in order to secure the advantages of uniformity during a period of great economic stringency, and to enable the Ministry to fulfil its growing duties in regard to safety conditions. The members of one Board only, that for the Leeds factories, maintained throughout an active and independent interest in the affairs of the filling factories which they managed, and consequently uniformity of method was seriously threatened; but any attempt to strengthen the Ministry's control met with strong local opposition from men who were justly conscious of the great successes of their early efforts to ensure large and speedy production.

III. Direct Control by the Ministry.

It was evident, in quite early days, that the Ministry might in any particular case feel obliged to take over the management of a factory which was not satisfactorily run. Transference to the Ministry was far less invidious than transfer to another agency. Further, it was clear that much of the work to be done was so unlike anything that had formerly been known that it would be easier for the Government to shoulder the whole responsibility itself than to find any agent willing to do so.

There was a tendency, then, for work which had been ill done and for work of a type which had never been done to be undertaken directly by the Ministry. As a result, the proportion of national factories managed in this way increased as time went on. Many of the High Explosives Factories, four of the five Trench Warfare Filling Factories, and several of the Gun Ammunition Filling Factories were managed directly by the Government. But the Ministry to the end avoided direct responsibility for the Shell and Projectile Factories which could be managed on lines with which engineering employers were conversant.

Queensferry was the first and Gretna the second important factory to be managed directly by the Ministry. In the extreme shortage of engineers familiar with the construction of explosives and chemical plant, both factories were planned and erected by the Government's own engineers. Both were started up section by section, and there seems to have been no question from the beginning as to the control of the two factories by the Government.

In March, 1915, the High Explosives Branch of the War Department had secured a derelict engineering works at Queensferry, with a view to adapting it for the supply of explosives for the Army and Navy. The Admiralty, which had long wished to erect a factory whence it could obtain supplies independent of the War Office, brought its schemes to maturity and rejected any share in the Queensferry project at the end of June, 1915. The factory was at once handed over to

the Ministry of Munitions and placed under the factories branch of the Explosives Supply Department. A superintendent was appointed to manage the factory.

Gretna was the result of a scheme for the erection of a great national factory for the manufacture of propellant which was mooted by the Munitions of War Committee in May, 1915. The factory was to make cordite, R.D.B., newly evolved by the Research Department; it was to be on a vast scale so that it might fully meet all requirements; it was to be in an isolated place for purposes of safety. If the Government were ever to control a factory from its inception it was evident that such a factory was suitable for the experiment. Proximity to other factories, so often desirable, was the last thing that was required. Mr. Quinan himself supervised the planning of the factory in the Explosives Supply Department. Messrs. Pearson and Sons, Ltd., were made construction managers and given an extremely free hand in the erection of the factory so as to hasten matters, but the management was from the first in the hands of the officers of the Explosives Supply Department, a superintendent being appointed by the department to carry on the work as at Queensferry.

Of the other Explosives Factories which were taken over in 1915, Rainham was placed at first under an agency management, but direct control was taken in May, 1915, owing to the unsatisfactory progress. With one exception, the management was in the hands of a superintendent under the control of the Ministry in all the other Explosives Factories established as national undertakings during 1915. The exception was the perchlorate factory at Langwith, where the Power Gas Corporation were at first appointed consulting engineers and later a construction manager was put in charge of the works. But the management was brought into line with that of the other Explosives Factories in July, 1917.

The wood-distillation factories transferred by the Office of Woods and Forests to the Ministry were, with the later factories, managed by superintendents under the control of the Propellants Branch of the Ministry. Explosives Factories acquired or built after 1915 and placed under direct State control were managed in the same manner. Of these Litherland, Dundee and King's Lynn were acquired from contractors. When the later programme of the end of 1916, and beginning of 1917 involved the building of several large factories, the Ministry undertook direct responsibility for the erection and management of Avonmouth, but left the control of Lytham, Greetland and Bradley to contractors, since it was easier to get experienced agents for these later picric acid factories than it had been for the earlier T.N.T. factories.

It has already been shown that Filling Factories of a certain type were placed under the control of local Boards, and an equal number under that of certain firms which were thought to have special facilities for managing them. The general policy was to have the factories for the unfamiliar operation of shell filling under direct State control, whilst component filling was left mainly to the trade. In general, a large degree of autonomy was left to the managing directors. They

were frequently entrusted with the construction as well as the management of the factories. For instance, Lord Chetwynd, who was managing director of Chilwell, was entirely responsible for the selection of the site, the design, construction and equipment of the factory as well as for its management. Mr. Blyth, who was managing director both of Hayes and Southwark, also had extensive powers. Central control over the Filling Factories was tightened in time by the Ministry's instituting closer supervision over finance and safety conditions. At first no definite financial supervision was imposed and the lack of such supervision, involving as it did the lack of any consistent policy in the arrangements of the factories, hindered rather than helped their development.

All the Trench Warfare Filling Factories, with the exception of Denaby, were directly controlled by the Ministry. This was not the original intention, which had been to place all of them, except Watford, under the management of private firms. But a change in personnel at headquarters and difficulties experienced in getting the contractors to make any reasonable financial contract forced the Ministry to undertake the management itself.

Certain factories, unique of their kind, were also brought under the direct management of the Ministry. Into this category come the factories built for experimental work, such as the Coundon National Small Arms Ammunition Factory, built in the summer of 1917, and placed under the supervision of a manager appointed by the Ministry. The Southampton Government Rolling Mills was also controlled directly by the Ministry; in this instance the superintendent had considerable powers, being entrusted with the erection and equipment of the factory as well as with its management.

With the elimination of Messrs. Armstrong, the original agents for the National Projectile Factory at Birtley, and the transfer of the National Shell Factories, Ailsa Craig and College Park, to the control of the Ministry in circumstances already described[1] the tale of factories under this form of management is practically complete. It may be said roughly that the need for the simultaneous erection of a large number of Filling Factories and the lack of industrial experience in this work forced the Government to adopt this method deliberately for a large proportion of such factories: that with certain very large schemes for Explosives Factories, it was from the outset considered the best method, as in the case of Gretna, Queensferry, and Avonmouth; but that in other cases attempts were generally made to secure some other means of controlling the national factories, direct control only being resorted to when other methods failed.

IV. Success of Different Methods of Management.

No exact test of the comparative success of the various processes of management can be used. Speed in construction and costs per unit of output would appear to give accurate measurements in time and price. But the number of factories which can be compared on these points is too small to afford any basis of comparison.

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[1] See above, pp. 41, 77.

In so far as given types of management were reserved for given types of factory, no definite comparison can be made. The cost of the shell produced under the management of local Boards cannot be set against the cost of the heavier type of shell produced in the Projectile Factories managed by agencies. The length of time it took to erect the Explosives Factories under the direct management of the Ministry cannot be measured against the length of time needed for the construction of the National Aircraft Factories, controlled by agencies. The Filling Factories indeed, furnished instances of all these types of management; but on investigation it appears that the difference in rate of construction arose rather from the nature of the work than from that of the management.

Again, when the Explosives Factories are considered, it would seem as though some exact comparison might be made. There were many such factories, some under agency, and some under direct management. Careful records of costs were made. But when these records are examined it is found that, owing to the large number of different explosives and to the varying size of the plant devoted to their production, no conclusion can be formed as to the efficiency of the various kinds of management. If the records for 1918 are taken with regard to two of the products manufactured most widely, viz., nitric acid and T.N.T., this is abundantly evident. Of eight national factories engaged in the production of nitric acid, four—Oldbury, Greetland, Craigleith and Pembrey—were worked by agencies, and four—Litherland, Queensferry, Penrhyn Deudraeth and Gretna—were managed directly by the Ministry. The four factories with the lowest costs were Greetland and Pembrey, Gretna and Queensferry, *i.e.*, half under one type of management and half under the other. The same consequently was true of the four with the highest cost. The costs at Greetland under agency management were noticeably more than at any other factory, but as this was not the case in other factories managed in the same manner it proves nothing. A similar lack of results is found on examining the costs of T.N.T. Of the six factories producing it half were under agency and half under direct management. Litherland and Queensferry were respectively the dearest and cheapest producers, and both were directly controlled by the Ministry, the difference here being attributable to the comparative advantages of large scale production on a well-planned plant. Pembrey, worked on an agency basis, vied with Queensferry in cheapness, and there was little to choose among the remaining factories as regards cost of production.

It may be suggested that if the elimination of the agents' profits by direct control did not lower the price of its product, the greater efficiency of agency management is proved. But it must be borne in mind that, though the sum total of the agents' profits was great, they were but a small element in the cost of each unit of production, and their elimination could make but a very small difference in the price of each ton of T.N.T. The instances given are too few, the variations in price too wide for any conclusions on this point. With the figures given, profits are an unimportant factor in the sum total of the costs.

So far only negative conclusions have been reached. Nothing has been advanced to prove the superiority of one method of management over another. But by studying more negative facts more positive results may be attained.

First it may be noticed that again and again, when the working of factories on an agency basis was unsuccessful, the management was transferred to the direct supervision of the Ministry with a comparative degree of success. Secondly, that complaints were made as to delay in starting production, both in the National Shell and in the National Projectile Factories. Thirdly, that there appear on the whole to have been more difficulties connected with the working of factories under indirect than with those under direct control.

This does not, of course, prove that direct control would have succeeded at once where agency management failed. But it is in favour of direct control. If, however, the Ministry had assumed direct control of all factories, they would probably have met with far greater difficulties in the quest for efficient managers than they experienced in dealing with experts on local Boards and private firms.

It should be noted finally that although the Ministry successfully transferred several firms from an agency basis to direct control, it also made some unsuccessful ventures when undertaking full control from the beginning. Cases of conspicuous success and conspicuous failure existed under every method of management, and the method of direct control was no more free from failure than other methods were from success. Two of the most efficient Explosive Factories—Greetland and Pembrey—were worked on an agency basis, and these and many others may be set against the unsatisfactory conditions at Lytham and elsewhere. Direct control had great success at Gretna, and in other factories, but it did not achieve it at Litherland. Nor did direct control prevent something of a fiasco at Avonmouth or make the Government Rolling Mills profitable. Yet here again the balance remains somewhat in favour of direct control. For, as has been shown, this form of management was generally introduced either because another had failed or because no other could be secured. Consequently, it may be said that on the whole the method of direct management by the Ministry was employed in factories in which the difficulties were greatest. If, therefore, this form of management has no greater proportion of failure to show than any other, it would seem that its efficiency might be considered greater.

The data are insufficient for more than a tentative judgment. The one thing that remains clear is the great advantage of using different methods and so adapting administration to varying circumstances and conditions. Success in administration is seen to be largely independent of any particular system or method of management.

CHAPTER V.

CONTRIBUTION OF THE STATE FACTORIES.

The national factories were of value in the first instance as a means of increasing supplies, of breaking down monopolies and of lessening dependence on imported goods. These advantages, however, were common to all methods of increasing production, and other advantages may be noticed as peculiar to nationalisation.

In comparing results in old and new factories, and particularly when estimating the achievements of the war time emergency factories, it is necessary to bear in mind the highly specialised character of the latter. They were each one designed *ab initio* for bulk production within a comparatively limited range. They proved highly efficient for their particular work, and achieved results often superior to those obtainable in older establishments. Yet this gratifying result was not secured without sacrificing the balance and elasticity of less specialised productive units, and in fact when submitted to the searching test of post-war utility there were very few that could be utilised as they stood for peace-time purposes.

Large scale production, standardisation, scientific management, improved labour conditions, all the gains of these and kindred methods must leave some mark on industry. The experience gained cannot be lost. Yet the effects may be over-estimated, for to an important extent the war-time experience of the national factories is inapplicable to peace-time conditions. Lessons learned in the Explosives and Filling Factories are not all applicable to industry in general. Moreover, the possibility of large scale production, standardisation, etc., was largely due to the peculiarities of the war demand. Such methods could be carried much further when tons of goods of a given kind were demanded daily. The demands of peace are more varied and call for more elasticity and less mass production. Still, efficient methods having once been practised will, no doubt, spread so far as they are applicable to industries other than those in which they were first used. There can be no doubt that some results are already to be seen in things relating to labour, and to some extent in other matters.

I. Reduction in Costs.

During the war the State became a purchaser on so vast a scale that a true knowledge of the costs of production became a matter of great importance. The buyer of a few goods may pay something for his ignorance of the actual costs, and still more for his ignorance

of means by which those costs could be reduced, but it is not worth his while to become learned in the manufacturing expenses of the various goods he buys. But when manufactured goods are bought by the thousand and by the ton the purchaser may save much if he becomes something of a manufacturer and discovers the cost at which goods can be produced. This is all the more vital when, as during the war, the ordinary marketing is hindered by transport and other difficulties and when, as with munitions, constant changes in orders, involving the use of new methods, are made. There was neither scope nor time for ordinary competition to do its work.

As a result Government factories were of the greatest value both in indicating the lowest costs at which various munitions could be manufactured, and as research centres in which methods of lowering those costs yet further might be discovered.

Not only did the national factories serve these purposes, but they were the basis of an elaborate system of costing, by means of which "bogey" costs could be evolved, giving the costs of raw materials, of labour, and of every process at any given moment and showing the ideal proportion to be attained between the various items of expenditure.

The cost returns furnished by the national factories were partly instituted as a check on undue expenditure. But it was recognised from the first that they would serve the further purpose of diminishing trade prices. Constant references to their success in this matter are to be found in the minutes of committees dealing with finance and economy. For instance, at a conference of National Filling Factory accountants in January, 1917, the chairman, Mr.Webster Jenkinson, mentioned the various purposes to which the cost returns from the National Filling Factories were put by the Ministry and explained how they had already been of considerable use in the reduction of prices charged by private contractors for filling work.

As time went on the costing system became more elaborate. The chief production costs per unit shown in the factory returns were: (*a*) labour; (*b*) materials; (*c*) overhead charges, with the exception of depreciation and interest which were dealt with at headquarters. Rejections and waste of material were taken into account in arriving at the cost. In some factories statistical information as to the production per worker and time per unit was obtained.

The costs of shell produced in the National Projectile Factories compared with the prices paid for contractors' shell show very favourable results, and it was reckoned that at the end of 1917 a total expenditure of £14,659,827 on shell from the national factories had meant a saving of nearly £3,000,000 on what would otherwise have been paid to contractors. It will be seen from the table below that in very few cases was the cost of shell produced in the national factories above the average contract price.

COMPARISON BETWEEN COSTS IN NATIONAL PROJECTILE FACTORIES AND CONTRACTORS' PRICES, 1917.

National Factory.	Designed Capacity per week.	Cost per Shell.	
		Cost in N.P.F.	Average Contractor's Price.
	I. 15 in., H.E. IV.	s. d.	s. d.
Leeds, Hunslet	250	772 0	985 0
	II., 12 in., H.E., IV.		
Renfrew	500	441 2	422 0
	III., 9–2 in., H.E, IX., X.		
Leeds, Hunslet ..	2,000	191 0	217 6
Leeds, Newlay ..	2,000	213 9	,,
Sheffield	4,000	153 10	,,
Nottingham	2,000	169 0	,,
Renfrew	—	195 0	,,
Lancaster	3,500	172 8	,,
	IV., 8 in., H.E., III. & V.		
Cathcart	2,000	129 8	156 3
Birtley	4,000	103 1	,,
Cardonald	6,000	92 4	,,
	V. 6 in., H.E., III. IV, VI, IX, XVI.		
Leeds, Armley Road	5,000	64 0	69 3
Birtley	6,000	56 11	,,
Nottingham	6,000	60 6	,,
Lancaster	6,000	82 2	,,
Mile End (Cardonald)	6,000	53 1	,,
Hackney Marshes ..	15,000	74 0	,,
Dudley	6,000	68 10	,,
	VI., 60 Pdr., Shr., II.		
Birtley	4,000	56 3	57 6
Renfrew	10,000	54 8	,,
Lancaster	6,000	49 11	,,
Dudley	17,000	56 2	,,
	VII., 60 Pdr., S.K., & H.E., VI, VII, VIII.		
Cardonald, Moss End	6,000	37 6	51 3
Templeboro'	21,000	47 0	,,

Similar facts can be quoted with regard to the Explosives Factories. T.N.T. was produced in the national factories in 1915-1916 at an average cost of 34 per cent. below the price charged by contractors. The next year the cost was 42 per cent. less than contractors' prices, and this in spite of the fact that the contractors' prices had fallen. In some cases, there were no prices with which costs in the national factories could be compared. In others, where national factories were a late growth, lack of experience in production made the State costs higher than trade prices, and there was no time before

the end of the war to perfect processes. This was the case with the production of picric acid; factories had no sooner been created for the manufacture of this explosive than the demand fell, and only those factories in which state manufacture had been exceptionally successful continued their work. In some few instances the need for economy in materials led to the use of methods in state factories which were more expensive in labour than those employed elsewhere. This happened for a short period in the state production of ammonium nitrate.

It is, however, abundantly clear that although the national factories cost much, they saved much. At Gretna, for instance, it was reckoned that the difference between the cost of propellants purchased in America at the time the factory was begun and the cost of production at the factory was so great that "eight months' full output of the factory taken at this difference is equal to more than the capital cost of the factory." It should be observed in this connection that the cost of building Gretna amounted to over £9,000,000, *i.e.*, more than one-eighth of the total expenditure on all national factories.

Further, part of the cost of munitions produced in the national factories was reckoned as depreciation, and this, together with the saving on contractors' prices wiped out much of the cost of building. To take the most expensive group of factories, those for manufacturing explosives, it was estimated in May, 1918, that the cost of the factories to 31 March, 1918, had been £20,446,539, the saving on contractors' prices £11,368,237, the depreciation included in cost of production, £6,202,479, these last two items making a total of £17,379,574; which when subtracted from the cost of construction leaves only £3,066,995 as the net cost of the factories. This sum would be diminished by output for a greater length of time and might finally be made a minus quantity by the sale of plant and buildings.

The gain was far greater than appeared, and in fact it was less than would have been shown by similar figures given a year earlier, because of

> "reductions in Contract prices, which have been secured partly by reason of the low cost of production at Government factories, which has assisted the Department (of Explosives Supply) in determining what would be a reasonable price to pay to Contractors." Further, "It has to be pointed out that without the Government factories this production could not have been attained in this country, and the erection of factories like Gretna and Queensferry has avoided the necessity of contracting in the United States of America at considerably higher prices than were payable in this country."

Cordite serves as an illustration of both points.

(1.) The average contract price of R.D.B. cordite fell from 2s. 9d. in 1915/16 to 2s. 3¼d. in 1917/18.

(2.) But for the state manufacture of cordite it would have been necessary to purchase the alternative propellant powder

nitro-cellulose powder from the United States of America at 1 dollar a pound,—though again the competition of Gretna cordite with American nitro-cellulose powder secured a reduction in the price of the latter to 50 cents.

Thus the fact that there was an actual margin of £868,999 between the cost of cordite at the national factories and the average contractors' price is far from representing the true facts and the real gain of state production.

II. Economy in Materials.

If the saving of expense was of great importance to the State, saving of material was vital. Again and again it was admitted that munitions must be secured "at any cost," and factories were carried on even when their costs were higher than general prices warranted because their products were indispensable. But there was always a fear that at no cost could the supplies of certain raw materials be increased, a fear that was converted into a certainty as time went on.

The national factories were of the greatest service in meeting this difficulty. In the first place they facilitated the central control and therefore the profitable distribution of materials. Further, by means of the costing system they were able to show the largest possible output which could be obtained from any given unit of raw material and the extent to which rejections could be reduced.

In very early days managers of national as of other factories bought in the open market. But returns from the national factories showed such great variations in the price paid for goods, and difficulties arose so swiftly from the competition of the Government with private firms for the requisite materials, that state control over supplies was extended from one type of raw material to another. Eventually, most of the important materials for shell making were bought in large quantities by the Government and issued to producers at uniform prices; in some cases the Government purchased nearly the whole of the available supply and the whole supply of platinum, aluminium and antimony was in the hands of the Ministry. Steel forgings were supplied by central purchase; machinery also was centrally purchased under the direction of the Machine Tool Department.

Returns, showing the number of rejections from various factories, did much to reduce the number of such rejections. They were given in great detail in the Filling Factories, and at first there was a very wide discrepancy between the number of shell rejected from the less, as compared with those rejected from the more efficient factories. The circulation of lists giving comparisons of results quickly produced an effect; and was of great service in economising labour and material.

Efficiency costing, which was brought to a very high pitch of perfection with regard to the Explosives Factories, was directly helpful in saving raw material. The second *Report on Costs and Efficiencies*,

for H.M. Factories under the Explosives Supply Department (September, 1918) gave a remarkable record of reductions in the use of raw materials and the circulation of this and earlier accounts was intended to stimulate similar economy of material in all factories.

To give a few instances: at Greetland the amount of phenol employed in the manufacture of each ton of picric acid was reduced from 0·561 tons at the end of 1917 to 0·532 tons in June, 1918. At the same factory during the same period, the $NaNO_3$ usage was reduced from 2·165 tons to 1·961, and of H_2SO_4 from 2·742 tons to 2·014. At Queensferry in the manufacture of each ton of tetryl the HNO_3 usage was reduced from 2·894 tons early in 1917 to 2·328 tons in June, 1918.

In the manufacture of ether the efficiency of the alcohol used per ton of ether made, rose from 96·1 per cent. at Gretna in the first half of 1917 to 98 per cent. in the first half of 1918. The efficiency at Pembrey fell slightly during the same period from 94·8 per cent. to 94·2 per cent.

In the production of each ton of T.N.T. the usage of materials fell, in all the national factories taken together, between the end of 1916 and the beginning of 1918 to the following extent:—Toluene, 0·516 to 0·482 tons; H_2SO_4 usage 0·640 to 0·409 tons; HNO_3 usage 1·239 to 1·005 tons.

Numerous instances of the same nature might be cited, and the prevailing impression received from reading the report is one of continually increasing efficiency in the use of material.

III. Improvements in Processes.

The national factories served as laboratories for the discovery of new and improved methods and for putting into practice experiments suggested by the Research Department at Woolwich. Even in the Projectile Factories managed by experienced armament firms suggestions were made and acted upon which were found to be of value throughout the industry. This was of more common occurrence in the Explosives Factories and in the Filling Factories where much of the work was experimental. Many discoveries were made, many experiments tried which perfected old processes, economised material, and in some cases, revolutionised production.[1]

The State as a large purchaser and a large scale manufacturer found it worth while to introduce and to attempt methods which would have been too risky for any one small firm. Once new processes had been proved by the State small firms could also abandon stereotyped processes, and so the gain became general.

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[1] See above, p. 69.

IV. Safety Precautions.

The guarding of munitions factories from sabotage or hostile attack was the concern of a special Military Adviser acting in conjunction with the War Office. Arrangements for the large numbers of police needed for such establishments as Gretna were made by a special Committee on the Policing of Munitions Factories. Fire services and fire prevention in all munition factories, national or trade, were undertaken by a Fire Protection Committee. Under the Explosives Acts, the Government was responsible for safety conditions in all state factories. The experience gained from accidents in these and other works was carefully recorded by a Committee on the Cause of Explosions appointed by the Minister of Munitions in February, 1916, and the regulations put in force were based upon the knowledge so acquired. A great deal of munitions work was of a highly dangerous character, not only because of the risk of explosion but because of the injury to the health of the workers. Where this was the case it was felt that the Government was likely to pay more attention to safety precautions than private firms, and that it was at any rate advisable for national factories to be built which should serve as models to private firms.

V. Output.

Sufficient has been said to show the diversity of method employed in producing various munitions of war. The actual contribution of the State factories to the output of the most important classes of munitions was very large. Statistics for some representative stores are given in the table, which follows. This statement also shows the proportion of the total supplies derived from the State factories, both the old-established Ordnance Factories and the emergency factories which owed their existence to the war. This proportion ranges from 4.7 per cent., the proportion of trench mortars made in the Ordnance Factory during the first two years of the war only, to 78 per cent., the proportion of gun ammunition filling undertaken at the Royal Laboratory and in the National Filling Factories, and 98·6 per cent., the corresponding figure for the filling of trench mortar ammunition.

The comparison of the State factory output with the total home output is even more significant. The proportion of trench mortars from State factories remains unaltered at the bottom of the list, since none of these were imported, and being of simple construction it was the Ministry's policy to obtain them from the small engineering shops of the country. Similarly, the figure for filling trench mortar ammunition remains unchanged, as no filled bombs were purchased from abroad. On the other hand, the proportion of filled shell from State factories to the total home production is raised to 86.4 per cent., since much of the ammunition from other sources was obtained as complete rounds purchased in America.

TABLE SHOWING THE OUTPUT OF THE STATE FACTORIES TOGETHER WITH ITS PROPORTION TO HOME PRODUCTION AND TO THE TOTAL SUPPLY OF CERTAIN STORES.

STORE.	HOME.				ABROAD.	GRAND TOTAL.	Percentage of State Factories Output to Grand Total.
	Total Home.	Contractors	State Factories.	Percentage from State Factories			
Empty Shell.			[O.F., N.P.F., N.S.F.]				
Aug.–Dec., 1914 ..	245,400	168,100	77,300	31·5	—	245,400	31·5
1915 ..	8,314,500	6,904,800	1,409,700	17·0	8,022,400	16,336,900	8·6
1916 ..	33,688,500	25,154,500	8,534,000	25·0	41,848,500	75,537,000	11·3
1917 ..	56,638,800	39,307,800	17,331,000	30·6	27,533,000	84,171,800	20·6
1918 ..	63,820,900	45,461,000	18,359,900	28·8	18,330,000	82,150,900	22·3
Total	162,708,100	116,996,200	45,711,900	28·0	95,733,900	258,442,000	17·7
Filled Shell.			[O.F., N.F.F.]				
Aug.–Dec., 1914 ..	527,800	—	527,800	100	—	527,800	100
1915 ..	5,939,000	859,900	5,079,100	85·5	1,487,300	7,426,300	68·4
1916 ..	45,859,900	8,177,700	37,652,200	82·2	5,736,100	51,596,000	72·9
1917 ..	76,248,700	9,928,700	66,320,000	87·0	11,428,000	87,676,700	75·6
1918 ..	67,439,300	7,644,200	59,795,100	88·7	2,375,200	69,814,500	85·7
Total	196,014,700	26,610,500	169,404,200	86·4	21,026,600	217,041,300	78·0
Rifles.			[O.F.]				
Aug.–Dec., 1914 ..	120,093	68,517	51,567	43·0	—	120,093	43·0
1915 ..	613,461	341,605	271,856	44·3	2,650	616,111	44·0
1916 ..	952,928	534,645	418,283	43·9	406,758	1,359,686	30·8
1917 ..	1,205,672	565,559	640,113	53·0	952,643	2,158,315	29·6
1918 ..	1,062,072	435,742	626,330	59·0	—	1,062,072	59·0
Total	3,954,226	1,946,068	2,008,158	50·8	1,362,051	5,316,277	37·6
S.A.A. (Thousands of rounds)			[O.F., G.C.F., Coundon.]				
Aug.–Dec., 1914 ..			Included in	Figures	for 1915.		
1915 ..	1,194,894	948,127	246,767	20·7	262,062	1,456,956	16·9
1916 ..	2,729,326	2,112,772	616,554	22·6	592,600	3,321,926	18·5
1917 ..	3,136,987	2,337,944	799,043	25·5	97,464	3,234,451	24·7
1918 ..	3,436,602	2,385,300	1,051,302	30·6	—	3,436,602	30·6
Total	10,497,809	7,784,143	2,713,666	25·9	952,126	11,449,935	23·7
Trench Mortars			[O.F.]				
Aug.–Dec., 1914 ..							
1915 ..	12	—	12	100	—	12	100
1916 ..	976	480	496	51·0	—	976	51·0
1917 ..	5,554	5,163	391	7·0	—	5,554	7·0
1918 ..	6,194	6,194	—	—	—	6,194	—
Total	6,360	6,360	—	—	—	6,360	—
	19,096	18,197	899	4·7	—	19,096	4·7
Trench Mortar Ammunition (Filled).			[O.F., T.W.F.F.]				
Aug.–Dec., 1914 ..	545	—	545	100	—	545	100
1915 ..	411,234	150,140	261,094	63·4	—	411,234	63·4
1916 ..	6,464,989	85,932	6,379,057	98·8	—	6,464,989	98·8
1917 ..	5,051,967	—	5,051,967	100	—	5,051,967	100
1918 ..	4,439,945	—	4,439,945	100	—	4,439,945	100
Total	16,368,680	236,072	16,132,608	98·6	—	16,368,680	98·6
High Explosive.	*Short Tons.*	*Short Tons.*	*Short Tons.*	*Short Tons.*	*Short Tons.*	*Short Tons.*	*Short Tons.*
			[H.M.E.F.]				
Aug.–Dec., 1914 ..	434	434	—	—	—	434	—
1915 ..	16,923	13,248	3,675	21·7	3,283	20,206	18·2
1916 ..	109,578	88,783	20,795	19·0	17,657	127,235	16·3
1917 ..	230,140	156,847	73,293	31·8	29,526	259,666	28·2
1918 ..	203,109	64,621	138,488	65·2	2,047	205,156	67·5
Total	560,187	323,936	236,251	42·2	52,513	612,700	38·6
Propellant.			[O.F., H.M.E.F.]				
Aug.–Dec., 1914 ..	5,298	4,038	1,260	23·8	—	5,298	23·8
1915 ..	12,438	8,784	3,654	29·4	13,535	25,973	14·1
1916 ..	29,617	22,392	7,225	24·4	54,594	84,211	8·6
1917 ..	98,778	49,065	49,713	50·3	106,031	204,809	24·3
1918 ..	77,258	32,644	44,614	57·7	52,938	130,196	34·3
Total	223,389	116,923	106,466	47·7	227,098	450,487	23·6

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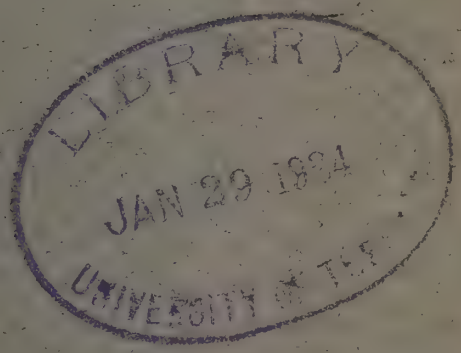
HISTORY OF THE MINISTRY OF MUNITIONS

VOLUME VIII

CONTROL OF INDUSTRIAL CAPACITY AND EQUIPMENT

PART II

THE NATIONAL FACTORIES



1922

VOLUME VIII

CONTROL OF INDUSTRIAL CAPACITY AND EQUIPMENT

PART II

THE NATIONAL FACTORIES

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PREFATORY NOTE.

It is intended that the chapters which follow should record, however inadequately, the achievements of the various national factories during the war. Accounts of the establishment and work of individual factories have been grouped under the main classes into which these factories generally fell for administrative purposes. The groups have been arranged roughly in chronological order, beginning with the Royal Ordnance Factories which were already in existence at the outbreak of war and ending with the National Aircraft Factories which were still in course of erection at the close of hostilities. A chapter[1] has also been added on the other miscellaneous, but numerous, factories which were controlled by the Ministry of Munitions for multifarious purposes. Within this chapter also the various groups have been arranged in approximately chronological order.

Owing to the diversity of the work undertaken by many factories, it has not been practicable to classify them according to the operations which they performed. State manufacture of guns, for instance, was carried out at the Royal Ordnance Factories and at certain Shell and Projectile Factories. In consequence, several important factories belonged to more than one class at different periods of the war. For instance, the factories which were converted to gun manufacture were classed during the latter part of the war as National Ordnance Factories. The introductory statement on each class of factories should form a general guide in this respect.

Considerable difficulty has been experienced in defining the term "national factory." To have limited it to establishments under the direct control of the Ministry would have ruled out very important classes which were administered by agents, as, for instance, the National Projectile Factories. An agency agreement, however, approaches very nearly to the cost plus percentage type of contract, under which the Ministry often bore the capital expenditure and paid the actual cost of operating a factory. Roughly speaking, such agreements have been included when the agent definitely undertook to operate the factory on behalf of the State. The net has been cast somewhat widely to take in establishments where there were special reasons for claiming Government control, such as the Gadbrook Factory, which was accounted a national factory for the purposes of safety conditions only. No attempt, however, has been made to include all works whose names imply state-ownership, such as "H.M. Potash Factory, Oldbury,"[2] or other factories, which were similarly intended as national works, but were eventually operated by contractors, as, for example, the Trafford Park Tractor Assembly Factory.[3]

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[1] Chapter IX.
[2] Vol. XI, Part III, p. 76.
[3] Vol. XII, Part VI, p. 5.

State-owned plant within the works of contractors has also been excluded, even when it was operated by the servants of the Department, as was the case, for instance, with various experimental plants. Neither has any account been given of the numerous establishments which were engaged upon research, even upon a semi-manufacturing scale. A list of these will be given elsewhere.[1] The term " factory " has been taken to include those works which undertook manufacture, and in some cases salvage and repair. It accordingly excludes the large classes of inspection and storage depôts, mines, quarries and other similar undertakings which were controlled by the Ministry. The schedule of factories which is given in Appendix IV shows the main details relating to each of the factories included in this account and denotes the stage reached in the development of state manufacture at any point of time during the war.

The capital expenditure on the factories has been taken from the balance sheets for March, 1918, or March, 1919, whichever figure best showed the actual cost of the factory. The figures relating to labour have been taken throughout from the monthly Reports on Labour in Government Establishments, prepared by the Intelligence and Statistics Section of the Ministry. The introductory statements relating to the more important classes of factories aim only at showing the chief characteristics of the various types. They include some details touching schemes for erecting national factories which did not materialise and touching some minor establishments of which no detailed account appears.

The general circumstances which attended state manufacture on the enormous scale to which it was developed by the Ministry of Munitions have been described in the preceding section of this History.[2] The narratives, which follow, will be found to contain abundant evidences and illustrations for the conclusions there drawn. An account of the policy in regard to the post-war disposal of the national factories is given elsewhere.[3]

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[1] Vol. IX, Part II, Appendix IV.
[2] Vol. VIII, Part I.
[3] Vol. II, Part I, Supplement.

CHAPTER I.

THE ROYAL ORDNANCE FACTORIES AND THE ROYAL AIRCRAFT ESTABLISHMENT.

I.—Introduction.

There existed at the outbreak of war, four state-owned undertakings for the manufacture of munitions. Three of these were old-established factories engaged upon various classes of equipment. They were the Royal Ordnance Factories, which included the group of factories forming the manufacturing establishments at Woolwich Arsenal, together with the Royal Small Arms Factory at Enfield and the Royal Gunpowder Factory at Waltham Abbey. The fourth establishment, the Royal Aircraft Factory at Farnborough, was of comparatively recent date. All four were controlled by the War Department, although the output of the first three was divided between the two Services. Since 1909, the control of the factories at Enfield and Waltham Abbey had rested with a single head, the Superintendent of Waltham and Enfield, but the accounting for all three of the Ordnance Factories had been centralised at Woolwich, where the various manufacturing establishments in the Royal Arsenal were controlled by the Chief Superintendent of Ordnance Factories.

Certain classes of naval work, such as the filling of naval shell, were also carried out on a comparatively small scale at outstations or depôts. The account of these depôts, which were under Admiralty control, does not, however, come within the scope of this statement; while the general development and functions of the Royal Ordnance Factories have already been considered elsewhere.[1]

II.—The Royal Ordnance Factories, Woolwich.

(a) *Administration.*

The administrative organisation of Woolwich as it existed in 1914 had not materially changed since the reorganisation which took place in 1887 as a result of Lord Morley's Committee of Enquiry. The member of the Army Council responsible for the Ordnance Factories was the Master-General of the Ordnance, who controlled them through the Director of Artillery. The control exercised by the Director of Artillery was, however, confined principally to placing orders and giving instructions on technical matters from a military point of view, general control of the factories as a whole being left entirely in the hands

[1] Vol. VIII, Part I.

of the Chief Superintendent of Ordnance Factories. No codified statement existed as to the subjects which had to be referred by the Chief Superintendent to the Director of Artillery, but they were roughly questions as to personnel, pay, building services, machinery and purchase of material, and included all permanent promotions to the rank of foreman and above, special increase of pay, and increases affecting a class of employees. Practically all building services and all schemes for extensions to plant were referred for sanction. In normal times small purchases of material up to the value of £25 (or £100 for building) had been allowed without War Office sanction being required, with an extension to £100 for urgent cases. This limit was extended after the outbreak of war up to £500, monthly reports being rendered to the War Office. For urgent requirements War Office sanction was obtained after the event.

Orders to manufacture were conveyed to the Chief Superintendent of Ordnance Factories by means of the "extract." This document, which is of early origin, was devised to avoid the issue of direct orders by one official to another of equal rank, and consisted of an extract from the proceedings of a Board of Ordnance, which originally met at the Tower. Woolwich received its extracts through the Deputy Director of Ordnance Stores, Woolwich, for the Army, through the Superintendent of Ordnance Stores for the Navy, and through the Inspector of Royal Engineers' Stores for the Director of Fortifications and Works.[1] Allocation of work to the Ordnance Factories and trade firms respectively was settled at an allocation meeting consisting of representatives of the Admiralty and the War Office; but, except for indications as to urgency, priority of work was left to the discretion of the Chief Superintendent. The extract authorised the Chief Superintendent of Ordnance Factories to order raw material and plant, to engage labour and take any other steps necessary to produce the stores required. Raw material and trade supplies of plant were ordered through the Director of Army Contracts. The Deputy Director of Ordnance Stores, Woolwich, was an officer in the Department of the Quartermaster-General working under the Quartermaster's subordinate, the Director of Equipment and Ordnance Stores. He performed his functions as to the requirements of the Master-General of Ordnance under instructions from the Director of Artillery, and for the Quartermaster-General's stores through the Quartermaster-General, this dual authority being a relic of the time when the Quartermaster-General and Master-General of Ordnance were not separate officials at the War Office.

In August, 1914, the Royal Ordnance Factories at Woolwich were divided into departments as follows:—(1) The Royal Laboratory, where ammunition of all kinds was made and filled; (2) The Royal Gun Factory and Royal Carriage Department, dealing with guns, gun carriages, wagons, ammunition boxes and transport of various descriptions; (3) The Mechanical Engineer's Department, which dealt with

[1] Service stores for this department were ordered through the Deputy Director of Ordnance Stores, and experimental and departmental requirements through the Inspector of Royal Engineers' Stores.

the general engineering requirements of the whole Arsenal ; and (4) the Building Works Department, which was responsible for all buildings, extensions, road and railway traffic. Each of these departments was administered by a superintendent, and, in addition, the Chief Superintendent had a Military Assistant and a Civil Assistant, the latter dealing with accounts, finance, stores and pay, and the former assisting the Chief Superintendent on technical questions.

The Royal Laboratory, the department of the Ordnance Factories which expanded most during the war, underwent some reorganisation during that period. Prior to the war several officers, subordinate to the Superintendent of the Royal Laboratory and known as the Assistant Superintendent and Danger Building Officers, carried out all work in connection with explosives and the filling of small arms ammunition. In March, 1916, the Royal Laboratory was split up into three main divisions, the Filling Factories, Small Arms Ammunition Factories, under Controllers, and East and West Laboratory, under a Superintendent of the Royal Laboratory. The Small Arms Ammunition Factories dealt with the manufacture of small arms ammunition ; the manufacture of empty shells, bombs, primers, fuses, cartridge cases, etc., was carried out in the East and West Laboratory, while all filling was done in the Filling Factories, the Controller of which was also responsible for the tailoring, paper and leather factories.

The Gun Factory and Carriage Department were originally separate, but had been united under one superintendent in 1907 in order to secure greater co-ordination in the work of the two factories. From 1917 until the end of the war the Superintendent of the Gun and Carriage Factories had an Assistant Superintendent in the Gun Factory and in the Carriage Department a Deputy Superintendent, a first assistant in charge of the woodworking department and a second assistant directly under the Deputy Superintendent's orders. All these were military officers, and the Deputy Superintendent, who was a mounting specialist, had considerable latitude in control and in originating design, the Superintendent himself being a specialist in gun design.

When the responsibility for the supply of munitions was taken over in June, 1915, by the Ministry of Munitions, the control of the Royal Ordnance Factories did not at once pass to the Ministry, though it was understood that the whole of the technical resources and the experience of the staff should be made available to aid the development of munition supply. The position of the Factories was the subject of much discussion between the War Office and the Ministry, the principal object being to secure the transfer without dislocation of the work. The transfer was from the first considered to be merely temporary, and a scheme for a partial transfer was put forward, but it was finally recognised by all concerned that a complete transfer of full administrative control could alone be satisfactory, and this was agreed to in principle by both parties in August, 1915.[1] Mr. Lloyd George, then Minister of Munitions, allocated the control to the Director-General of Munitions Supply, whom he proposed to provide with a Consultative Committee

[1] HIST. REC./H/1122.11/1.

on Management. This committee, which was representative of the War Office and Admiralty and the chief supply departments of the Ministry concerned, was to be the medium for considering with the Chief Superintendent of Ordnance Factories and the Superintendent of Waltham and Enfield, matters affecting the placing of large programmes and questions of output. Extracts were to be placed by the Ministry, and a section (C.M. 7) was formed under Mr. Eric Geddes, then Deputy Director-General (C) of the Munitions Supply Department, to deal with extracts and correspondence with the Ordnance Factories relating to such questions as pay, personnel, extensions, supply of machinery, statistical returns as to output and progress and the quality and efficiency of products. The Chief Superintendent, Sir H. F. Donaldson, K.C.B., became technical adviser to the Ministry in September, 1915, and was succeeded at Woolwich by Sir Vincent Raven, K.B.E., who remained in control until June, 1917. Sir Vincent Raven's successor was General C. P. Martel, C.B., who had been Superintendent of the Royal Gun and Carriage Factory.

The Deputy Director of Ordnance Stores still retained the right to place extracts for less than £250, sending copies to the War Office and the Ministry, and the Ministry agreed to this on the assumption that such extracts would be for urgent stores, stipulating only that the Chief Superintendent should first be asked whether he could execute the order. The Admiralty and the Works Department still issued their extracts on Woolwich independently,[1] through the Superintendent of Ordnance Stores and the Inspector of Royal Engineer Stores respectively. The relations between the Ordnance Factories and the Ministry thus became for practical purposes the same as those between the Ministry and any large armament firm, the Chief Superintendent acting as a General Manager, and deciding what orders could be accepted.

Until the Ministry of Munitions took over the control of the Woolwich Factories, the Filling Factories were supplied with components by the Army and Navy Ordnance Departments. This arrangement cut across the policy of the Ministry, whereby it assumed responsibility for all stores until they were finally completed, and in January, 1916, it was arranged that the Chief Superintendent, represented by the Controller of Ammunition Components, should take over all the stores and buildings, all components in stock, the staff in charge of the stores, and some of the office staff, who had previously carried out this part of the duties of the Deputy Director of Ordnance Stores, Woolwich. From that time the Army Ordnance Department was concerned only with the receipt and storage of finished stores. The former arrangement still held good for naval stores, empty shell passing on arrival at the Arsenal into the charge of the Naval Store Officer, and being distributed by him for filling, and again passing into his charge after filling.

[1] Later, to avoid the difficulties incidental to two departments giving orders separately for filling ammunition at the Arsenal, a weekly meeting was held between Admiralty and Gun Ammunition Filling Department representatives when the Woolwich filling programme was arranged (C.R./Filling/384).

Section C.M. 7 was informed of the main items of work going through the Arsenal. The supply officers of the Ministry corresponded direct with the factories on matters concerning the particular store in which they were interested. This arrangement secured a fairly unified headquarters control, though the Consultative Committee was entirely abortive. In November, 1916, however, the work of Section C.M. 7 was discontinued, and all correspondence relating to manufacture, supply, and inspection was carried on direct between the department concerned and the Chief Superintendent, through the Central Registry. With regard to extracts, each department minuted the Chief Superintendent direct, giving the particulars of the extract which they wished to have issued. The extract was then prepared and returned by the Chief Superintendent if the order could be accepted. Sir Charles Ellis was nominated to deal with any matters of importance which might be brought before him by the supply departments or the Chief Superintendent, and he continued to do so until the formation of the Munitions Council,[1] when this responsibility passed to Sir Glynn West as Council Member G.

With the disappearance of Section C.M. 7 all centralised administration of the Ordnance Factories ceased. There was no one organisation within the Ministry to which the Chief Superintendent could look for assistance in general matters, and there was no one at headquarters with complete knowledge of all the productive activities of all the Factories, and able to advise on the nature and amount of work to be done there in the future. The Council Member had no one to whom he could delegate the work of dealing with the mass of detailed correspondence which flowed to and from the Arsenal. When Sir James Stevenson succeeded Sir Glynn West early in 1918 as Council Member responsible for the Ordnance Factories, he pointed out the unsatisfactory nature of this arrangement, and suggested the appointment, within the Ministry, of a Controller of Ordnance Factories,[2] who should be responsible to Sir James Stevenson as Council Member. He thought it was no function of a Council Member to deal with details such as came to headquarters from Woolwich, until they had been sifted and decisions as to policy were required.

By this time the productive capacity of the country for the manufacture of munitions had developed on such a scale that it was possible to give greater weight than had hitherto been found practicable to questions of economic and efficient production. A plan was under consideration for decentralising the manufacturing work of the Ordnance Factories to the new national factories, and the whole question was referred by the Minister of Munitions to a Committee of Enquiry, under the chairmanship of the Right Hon. T. McKinnon Wood, with the following terms of reference :—

> " To enquire into, and report upon the control, administrative organisation, lay-out and equipment of the Royal Ordnance Factories at Woolwich, and the nature and distribution of the

[1] HIST. REC./R/1122.1/1. [2] M.C. 537.

work carried on in them and at the Arsenal generally, and to advise the Minister of Munitions what, if any, changes are required.

"The Committee should have due regard to the importance of efficient and economic production, and the necessity for maintaining a reserve of productive power, and should give weight to the obligations of the Government as an employer to ensure the best possible industrial and housing conditions of the employees."[1]

The Committee made various recommendations as to the control and management of the Arsenal, but as their report was not presented until after the Armistice, it does not enter into the scope of this history.

(b) *The Site of the Factories.*

The suitability of Woolwich as a site for a national arsenal has long been a subject of debate. An ideal Arsenal should not be near the frontier,[2] but in consequence of the convenience of Woolwich for supplying the Navy and the colonies, its advantages for water transport and the political difficulties incident to any change, the discussions have never resulted in any action. A disbelief in the possibility of invasion and a desire for economy may have been contributing factors to this result. After the Crimean War there was a definite intention to remove the whole Arsenal to the Midlands,[3] but this opportunity was allowed to pass and the developments then made at Woolwich rendered any subsequent removal a very costly undertaking.

The question was raised again in 1907 by the Treasury on economic grounds. One of the terms of reference of a committee then presided over by Sir G. Murray was :

"to enquire into the effect which the concentration of Government manufacture and workshops in the Metropolitan Area has on rates of wages and cost of living, economy of production in time of peace, and power of expansion in time of war and to enquire what change, if any, is desirable in the present distribution throughout the country of such manufacture and workshops."

There was some ground for believing that the Government might well follow the example of private enterprise and seek some more favourable area of production nearer the sources of supply of coal and iron, where the burden of local rates was less and the prevailing standard of wages lower. It was evident, however, that a very considerable saving would have to be assured to balance the immense expenditure involved in acquiring a new site and providing new buildings, machinery and housing. The committee decided that to transplant the Arsenal as a whole seemed impracticable, and to transplant a part was useless in view of the interdependence of the different factories. They also felt that any such transfer might defeat its own object, since the sudden concentration of a large industrial

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[1] Hist. Rec./R/1122.11/8.
[2] *Proceedings of Royal Artillery Institution*, Vol. VIII, 110–11.
[3] Hist. Rec./R/1122.11/19.

population on the outskirts of an industrial town would go far to create a similar state of affairs to that from which it was desired to escape, while the selection of a site in a remote area would present housing difficulties and there would be no reserve of labour to draw on in an emergency. The proximity of Woolwich to Shoeburyness was also a strong argument in favour of retaining the Ordnance Factories at Woolwich, since it was very essential to have the factories near the proofing ground, and Shoeburyness had unique advantages as a proof range.

The frequent air raids which took place over Woolwich from the autumn of 1915 onwards raised the question again in an acute form, output being seriously affected on many occasions. In this connection, however, it has been pointed out that in view of the present range and capacity of aircraft no part of the United Kingdom can be considered immune from aerial attack.

(c) *Lay-out and Development.*

Even before the war the lay-out of Woolwich was bad. The policy adopted in the past had been to add extensions to existing shops wherever there was room. It soon became impossible to consider whether the shop was in the right position, as regarded the work it had to do for other shops, or whether transport arrangements were reasonable or not. The shop had to be put where room could be found, and as this went on for many years the result was an accumulation of buildings most inconveniently disposed for manufacturing purposes, and the whole of the more western area became so congested that transport difficulties made economic production impossible. The difficulty was not so apparent when working with the small numbers employed in peace time, but after war broke out the effects of congestion became very marked. The policy of keeping the shops confined to the west end of the Arsenal continued after the war began, chiefly because none of the schemes of extension were on a sufficiently large scale to warrant breaking new ground, eastwards on the marshes, where the swampy nature of the soil presented great difficulty in making secure foundations. Extensions which were made to the Gun and Carriage Factory, shell factories and inspection buildings added to the congestion in this area. It was only some of the larger schemes such as the small arms ammunition factories, new fuse factories, and later the new gun factory and the Q.F. cartridge factory No. 4, and the woodwork departments which were moved out into more open ground. In these cases it was possible to get a good lay-out which resulted in greatly increased ease and economy of working. Further accommodation was required, soon after the out break of war, in the danger buildings, and this was provided by adding extra buildings in the existing enclosures, by which the fire risks were dangerously increased.

The Arsenal railways, like the buildings, had been laid out in a piece-meal fashion and though they served sufficiently well under peace conditions they soon proved inadequate to meet the demands made on them by the war pressure. Transport difficulties were enhanced by

the fact that two gauges were in use on the railways, standard gauge and 18–in .gauge, and in many parts of the Arsenal the line was laid as a combined gauge. The objections to this combined gauge were apparent before the war, and when traffic increased, the system became very difficult to work where the combined gauge was required to do duty for four lines, one up and one down for each gauge. By degrees additional sidings were added, and as far as possible all new lines were laid in standard gauge. The mileage at the beginning of the war was approximately 90 miles, and the total length of railway track constructed during the war was 44 miles of standard gauge and 15 miles of narrow gauge. The total length of new roads constructed was 13 miles. The unsatisfactory lay-out of the factories was one of the greatest troubles in connection with traffic, owing to the large amount of haulage necessary, since the same components had to travel in the course of manufacture to two or three stores which were often widely separated. At one time a large amount of traffic, mainly for the Deputy Director of Ordnance Stores, was being sent to the Arsenal, merely for issue and accounting purposes, but this traffic was stopped early in the war.

When the Ministry of Munitions took over control, traffic congestion at Woolwich was very serious. The difficulties were to a large extent overcome by re-arrangement of interdepartmental traffic, regulation of the traffic to the Arsenal, diversion of unnecessary traffic and by increasing the loading and unloading staff.[1]

Expansion in the Gun and Carriage Factories took place in three stages, the first on the outbreak of war, the second on the formation of the Ministry and the third at the beginning of 1917. The first urgent requirements were for 60-pdr. and 18-pdr. guns, 4·5-in. howitzers, carriages and vehicles of all descriptions, and a little later for 6-in. Mark VII guns on field carriages and 8-in. howitzers, converted from 6-in. guns. The extensions made at this time were not large because the space available was very limited; the most important was the taking over of a large two-storied inspection building and fitting it as a machine shop for sight work. With regard to the woodworking shops little could be done as there was no room for expansion, and the pressure was enormous. The inconvenient position of the saw mills on Frog Island added greatly to the difficulty, the only means of access being a single line railway bridge, with an almost equally narrow outlet. The work at this time was seriously affected by the breakdown of some of the ancient machinery, a large proportion of the old plant giving out and needing repair or replacement. The Gun Factory was able to cope fairly well with the demands made upon it at the initial stages of the war, but the Carriage Department was obliged to call in the help of outside firms, in the manufacture of the simpler parts of mountings. This course was rendered possible by the fact that jigs and gauges for almost all items of the work were available for supply to the firms undertaking manufacture.

[1] Hist. Rec./R/1122.11/2; *cf.* Vol. VII, Part V, Chap. II.

The second expansion in these Departments occurred on the formation of the Ministry of Munitions in 1915 and was caused by increased demands for 8-in. Mark VI howitzers, 60-pdrs., and 4·5-in. howitzers and their carriages. The Carriage Department having no room for extensions had still to rely on the trade to meet the new demands. At the same time it had to supply large numbers of stampings for the new R.L. fuse factory, and to meet this a large amount of additional stamping plant was put into No. 2 Foundry, which worked exclusively for the Royal Laboratory. In the Gun Factory two stores were turned into machine shops, though they were most unsuitable for the purpose; and machinery was installed in every available space in existing shops. The expansion in 1917 was caused chiefly by the large number of 18-pdr. and other guns coming from overseas for repair, and by the great demand for guns for arming merchant ships. For this purpose new shops were imperatively required. It was decided at the end of 1916 to erect new shops for the Gun Factory on the site of the existing timber sheds, part of which had to be pulled down owing to a fire, and to remove the whole of the timber sheds to a more suitable site on the marshes. On the site thus left vacant, a machine shop, forge and tempering shop were erected. This plant was designed to deal with the repair of 250 18-pdr. guns and to make 50 new 4-in. guns for the Navy per month.[1] It was begun in February, 1917, part of the machine shop was at work in October, 1917, and the whole was complete in February, 1918. Later on the saw mills were removed from Frog Island to a site on the marshes near the timber sheds and new wheelers, carpenters, and wood machining shops, drying houses and stores were erected concentrating the whole of the woodwork on one site. The cost of the work amounted to about £1,150,000.[2]

Shell filling was concentrated at the Arsenal until the spring of 1915, and the filling factories at Woolwich filled by far the largest proportion of the ammunition issued until the National Filling Factories started up in the summer of 1916. The demands upon Woolwich for filling and completing ammunition and filling components on the outbreak of war were enormous and great extensions were necessary in the Royal Laboratory. The total area added to the R.L. Factories was 1,520,572 sq. ft.[3] The filling capacity of Woolwich was considerably in excess of its output of empty ammunition and components and within the first week of the war, by the adoption of night-shifts and overtime, the melt plant, which normally filled 10,000 lbs. weekly and had never dealt with more than 30,000 lbs. increased its output to 100,000 lbs.[4] This plant was at first used solely for lyddite filling, that being the recognised high explosive filling in August, 1914. Great developments in the use of high explosives entailed the necessity for providing T.N.T. filling sections, and two came into operation in April, 1915, though the second was not actually completed until the following September. The lyddite plant had also been extended, and the ultimate capacity of the melt plant for both

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[1] D.G.O.S./Woolwich/23.
[2] *Ibid.*
[3] Sec./Gen./802.
[4] *Ibid.*

explosives was estimated in July at 200,000 lbs. weekly. In the summer of 1915, three presses were installed to deal with 80/20 amatol, then used as a filling for 18-pdr. shell, and by the end of the year this plant was sufficient for dealing with 35,000 18-pdr. or 13-pdr. shells weekly.[1] The melt capacity was then 450,000 lbs. per week.[2] In September, 1917, an old lyddite factory was converted for filling naval ammunition with " Shellite " the method of filling having been worked out at Woolwich.[3]

In 1907, the Chief Superintendent of Ordnance Stores had become responsible for the storage of the stocks of high explosives which remained at the close of the South African War. The heavy pressure on the filling factories during the first two years of the war led to many additions to the danger buildings, and a corresponding increase in the expense magazines, which served not only the Ordnance Factory itself but also the riverside works which were engaged in completing ammunition. Full consideration to safety could not be given and it was considered that for a temporary expansion the increased risk was justifiable as a war risk. The magazines were mostly placed at a distance on the marshes and at Chislehurst, where some natural caves and dene holes had been acquired and adapted for the storage of explosives early in the war. Nevertheless, the question of danger at Woolwich caused considerable anxiety throughout the war. Explosives were stored on account of the Superintendent of Ordnance Stores, the Deputy Director of Ordnance Stores, and the Superintendent of Research, as well as for the use of the Filling Factories, and the works of riverside contractors. Of the 172 buildings which existed at the end of the war, each containing over 1 ton of explosive, only 15 complied with the regulations issued by the Home Office governing the distances which should be preserved between magazines and other danger buildings, and between these and private dwellings. There were 30 magazines and other buildings containing 3,562 tons of explosive situated within 100 yards of the river embankment and in many cases the distance was considerably less. A serious explosion might well have resulted in the flooding of the marshes. The small expense stores, many of which were unprotected by traverses or other adequate safeguards and were very close to the sheds in which large numbers of workpeople were employed, appeared specially dangerous. A fire in a shed, next one of the stores containing 15 tons of high explosive blistered the paint on the store walls, and it is worthy of note that the workers in the immediate locality, instead of flying from danger, heroically entered the store and busied themselves with removing to the centre of the shed the heavy boxes of explosives lining the walls. The general safety precautions which were enforced were, however, excellent and it was due to the extraordinary care with which these were enforced, and to the great knowledge of superintendents, managers and foremen of the nature of explosives, that Woolwich was immune from serious

[1] Hist. Rec./H/1520/6, p. 10 · D.D.G.(A.)9888.
[2] C.R./Filling/187.
[3] Sec./Gen./803.

explosions during the war. A great part of the difficulty arose on account of the large amount of filled ammunition which was stored at Woolwich, owing to the lack of accommodation elsewhere. It was found impracticable to do anything effective to improve the lay-out in this respect for some time, as the effects on production would have been too serious, but steps were taken to reduce the danger during the last months of the war.

From the beginning of the war the capacity of Woolwich for filling components was barely able to keep pace with demands, though extensive additions were made to the factories. Additions were made to the primer branch, cannon cartridge buildings, Q.F. cartridge factories and cap and detonator factories, entailing also a large increase of magazine capacity.[1] Three separate extensions to deal with fuses, gaines and minor components were begun in May, June and July, 1915.[2] New plant for a weekly output of 40,000 cases, 50,000 No. 83 fuses, 16,000 primers and 43,000 friction tubes was completed in the summer of 1916.[3] The extensions for filling both shells and components which were carried out during the latter half of 1915, included the erection of a new cartridge filling and assembly factory to double existing capacity. The extensions were designed to deal with the assembly of 100,000 18-pdr. shells weekly, either shrapnel or block filled.[4]

For the increased output of small arms ammunition extensions were also necessary. In September, 1914, an increase of at least 5,000,000 rounds a week was required, and sanction was obtained for buildings (factory C.F. 4) and plant for this purpose, and for increasing the output of shell fuses and cartridge cases.[5] In March, 1915, a proposal was put forward for a new factory working up to an output of 8,000,000 per week. The work was taken in hand in April, the factory being accommodated in certain existing buildings, formerly in the occupation of the Deputy Director of Ordnance Stores and the Chief Inspector, Woolwich.[6] In order to meet the heavy demands for ·303-in. Mark VII ammunition in the spring of 1916, a new factory with a capacity of 6,000,000 weekly was built at Woolwich in May (G.C.F. 2, afterwards known as C.F. 6).[7] The gauge shops at the Royal Laboratory were extended in August, 1916, by the addition of a large new shop.[8]

The developments described above were only the main extensions. The number and variety of the additions, which were made to the Royal Arsenal, the Dockyard and the Outstations maintained by the Chief Superintendent of Ordnance Factories during the war, can be

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[1] Sec./Gen./2239.
[2] C.R. 4436.
[3] 75/Gen./1982 ; 75/12/8967.
[4] D.D.G.(A.)9888, 12859.
[5] 75/14/1141.
[6] O.F./Gen./453.
[7] Vol. XI, Part VI, p. 51 ; *cf.* below p. 185.
[8] Vol. VIII, Part III, p. 15.

gathered from the list given in the footnote below.[1] A scheme for improving the lay-out of the Ordnance Factories was prepared in connection with the report of the committee referred to above.[2]

The supply of labour for the work of extension was difficult throughout the war, both as regards the quality and number of men employed. The difficulty was partially met by employing military labour and by obtaining navvies from Ireland. Building materials such as ballast, timber and steel were also difficult to obtain. A great deal of the building work in the Arsenal had always been carried out by direct labour, as the conditions under which it had to be performed so as to fit in with manufacture were such that it would have been almost impossible to arrange contracts. This was specially the case with work on the danger buildings. During the war the employment of direct labour was found to be the most speedy, though not the most economical method, since it would have been necessary had contracts been placed, to prepare plans and wait until the requirements of building were decided in considerable detail whereas by employing direct labour details could be arranged at the same time that work was proceeding.

(d) *Labour Problems.*

The pre-war policy of limiting the number of employees and staff at the Arsenal to a minimum, made the rapid and large expansion

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[1] In 1914: August, additions to proof butts and magazines; September, additions to inspection building for S.A.A. and shell, to buildings for filling H.E. shell, to Royal Carriage and Gun Factories for field artillery equipment, erection of new S.A.A. factory (C.F. 4), new cannon cordite cartridge range, new buildings for H.E. filling, new shell and metal case factory, conversion of Chislehurst Caves as magazines, erection of storage sheds on the football ground and hutments for 50 married workmen at Plumstead; October-November, extensions to R.L. danger-buildings; December, new tailor's shop and paper shop. In 1915: March, two new 250-ton H.E. magazines, large storehouses; April, establishment of inspection and storage accommodation at Park Royal, expansion of A.O.D. stores as a new S.A.A. factory (C.F. 5) and erection of new A.O.D. stores on the marshes, construction of housing at Well Hall, new coaling pier and 200-ton crane; May, additions to danger buildings (fuse and gaine-filling); June, new bomb and grenade stores; July, new case and fuse factory, extension to shops for painting and examining shell; August, new Naval magazines; September, additions to inspection and proof buildings; erection of hutments; October, large new factory, for assembling Q.F. ammunition (Q.F. C.F. 4), additions to proof butts and railway sidings, erection of four 200-ton cordite magazines; December, additions to buildings for receiving and examining fuses, new hostels and additional hutments. In 1916: January, additions to naval stores, to Park Royal inspection buildings, to the Arsenal dining rooms and to C.F. 3 for making Japanese ammunition; February, 2 storehouses for components; March, additions to Research Department; April, extensions to filling and chemical shell factories and to proof butts, additional heavy gun gantry, new hostels for women; May, new S.A.A. factory (C.F. 6), additions to police quarters; June, additions to Park Royal storage, additional office accommodation for Inspection Department, new building for gun inspection, new Mekometer House, new powder magazine; July, additions to S.A.A. factory (C.F. 6); August, extensions to Tailors', Paper and Leather shops, extensions to Chemical Department Laboratory, new women's hospital; September, additions to gun inspection buildings, to Research Department,

[2] *See* p. 7.

required when war broke out a matter of great difficulty. The work was of a specially skilled nature and insufficient allowance had been made for staff to train the new men, who were in many cases mechanics of an inferior order. The staff had been barely sufficient to carry on, even in peace time, and when war broke out night shifts had to be formed at once, and principal and assistant foremen to be found. As the permanent staff could not be enlarged, all those engaged during the war were temporary and it was found that the institution of temporary foremen was a failure. They never really separated themselves from the men, or took up a similar position to that of the established foremen.

The rates of wages were those of the London district, but the normal working week at Woolwich was 48 hours as against 52½ to 54 hours elsewhere. A night shift allowance of time and a half after midnight was paid in addition to overtime, and Sunday work was paid double time throughout the 24 hours.

For the first two years of the war the hours worked at Woolwich were extraordinarily long. Cases occurred where men had worked 12 hours' shifts on 27 days out of 28, and women and boys on 13 days out of 14. Women were frequently employed on 7 consecutive night shifts, normally of 12 hours. Men on overtime had sometimes worked up to 96 hours per week and boys up to 75.[1] Taking into account the comparative shortness of the normal working week and the overtime

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and to Experimental Signals Establishment, new gauge shops, new storage depôt; October, additional storage accommodation and Bond Stores, additional accommodation at railway sidings and new railway halt, additional dining room for women; November, new telephone exchange, new inspection building, new landing stages and ferry, additions to Gun Factory and Carriage Department and to dining rooms at Dockyard; December, extensions to shell store. In 1917: January, additional inspection offices, new store and dining room at Dockyard; February, extension of proof ranges; March, extension of Chemical Shell Factory, provision of electrical furnaces and connecting mains, conversion of quarters into offices at Pimlico; April, extension to Research Department, new dining room for boys; May, cloak-room accommodation at S.A.A. Factory; June, new dining room, new offices and shops for D.I.O.S.; July, offices for Inspection and Army Ordnance Departments; August, extensions to Research Department; September, rebuilding store at Q.F.C.F. 4; extension of empty shell sheds; new shellite factory in Cartridge Case Factory, adaptation of building at Raynes Park as Signals Factory; October, extensions to Signals Experimental establishment, alterations and additions to Signals factory, Teddington; November, new Battery Room at Dockyard, reconstruction of storehouse B. 37; December, conversion of H.E. buildings for amatol filling, new furnaces for destroying cartridges and building for breaking down enemy ammunition. In 1918: January, new shed for returned ammunition, additions to shifting house accommodation for trotyl workers and to accommodation for inspection and storage of naval components; February, foul drainage system for Magazine Area; March, buildings at Cricklewood adapted for Signals Factory, new dining room at Research Department, extension of R.A.C.D. Depôt, Battersea Park, new heating installation for A.O.D. Stores; May, alterations to R.A.C.D. Depôt, Old Kent Road; July, alterations and additions at Battersea Park R.A.C.D. Depôt; September, alterations and additions at Marylebone and Fetter Lane Clothing Depôts; October, extensions for amatol filling, new buildings for cleaning cartridge cases.

[1] Vol. V, Part III, p. 88.

allowance rising from time and a quarter to time and a half at the end of 2 hours, it is not surprising that exaggerated accounts of the wages obtained by Woolwich employees obtained circulation. A scrutiny of the wages earned at Woolwich for the quarter ending 5 July, 1918, revealed the fact that out of a total of about 66,600 employees, 427 earned an average of £10 a week or more. Of these, 205 were employed in the Gun Factory, 119 in the Small Arms Ammunition factories, 52 in the Carriage Department and 49 in the East and West Laboratory.[1]

Dilution of labour at Woolwich was begun when Sir Vincent Raven became Acting Chief Superintendent in August, 1915. The pre-war policy of employing boy labour had been continued until this time. It was, however, found to be inefficient, not only actually as compared with female labour, but on account of the constant turn over of boys, 1,400 having left during the first year of the war. The cartridge machines were run by boys, and a comparison of the overall efficiency of the various machines used in the operation with the efficiency of the six best boys showed a low general efficiency.[2] During the summer of 1916 men were being released for the Army at the rate of about 250 per week. In the Gun and Carriage Department female labour was not at once adopted but gradual dilution was effected by training a very low grade of mechanic for the high class work required in these factories. This was thought to be a better method than the introduction of women into work for which their fitness was questionable. Sir Vincent Raven was of the opinion that it was of primary importance that dilution should be effected independently of outside intervention, and by methods which should recommend themselves as suited to the peculiarities of the case. During the period in which he had been in control at Woolwich there has been no strikes, but situations had frequently arisen which required very delicate handling, and he considered that outside interference might involve very serious consequences.[3] The excellent relations between the authorities and the men were evidenced by the fact that the Chief Superintendent was accepted as the final arbiter in any questions arising from the dilution agreement. When Sir Vincent Raven first took control over the Arsenal in August, 1915, the total number of employees included no women and was 34,000. In November 1916 this number had risen to 68,000, and during that time 11,000 men were released to the colours, their places being taken by women: 20,000 women had been engaged. By May 1917 the number of employees had increased to 74,467 and there were between 25,000 and 26,000 women.[4] Dilution took place principally in the Royal Laboratory, the work of the Gun and Carriage Department being less suited to women. In the Small Arms Ammunition Factories, the percentage of skilled men was reduced from the pre-war figure of 18·3 to 15·2 in September 1916, and to 10·3 in September 1918.[5]

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[1] Sec./Gen./804.
[2] O.F./C/6.
[3] C.R. 4551.
[4] HIST. REC./R/1122.11/19.
[5] Sec./Gen./803.

The following figures show the dilution effected in the chief factories by August 1918.[1]

Factory.	Males.		Females.	Total.
	Under 18.	Over 18.		
Carriage Department	444	5,071	23	5,538
Gun Factory	113	3,569	146	3,828
East and West Laboratory	680	8,593	3,713	12,986
S.A.A. Factories	1,004	3,171	5,545	9,720
Filling Factories	1,071	8,032	11,692	20,795

The following figures show the numbers employed in the Arsenal during the war and the rapidity of its growth.[2]

Date.	Men.	Women.	Boys.	Total.
1 August, 1914	9,466	125[3]	1,275	10,866
2 January, 1915	19,378	194[3]	3,059	22,631
4 December, 1915	37,749	609	7,540	45,898
13 May, 1916	44,025	8,104	7,704	59,833
30 December, 1917	41,000	25,700	6,000	72,700
31 May, 1918	38,374	22,338	4,265	64,977
2 August, 1918	37,895	24,018	3,549	65,462

The questions of housing and transport to and from the Arsenal of the increasing numbers of employees became very serious. Woolwich had before the war been greatly overcrowded, and with the influx of some 60,000 new workers into the Arsenal the pressure became very great. A garden suburb of 12,000 houses was built at Well Hall early in 1915 by the Office of Works. Seven estates of bungalows were developed providing at the end of 1918 for 2,654 families, and residential hostels were erected to accommodate 750 boys, 2,600 women and 2,000 men.[4] During 1915 and 1916 the difficulty of getting to and from the Arsenal was found to be one of the most serious causes of fatigue to the workers. The establishment of a river ferry, the arrangement of better tram, omnibus and railway services and the careful arrangement of shifts remedied this to a certain extent. The shifts were arranged to distribute the passengers to and from the Arsenal as far as possible at intervals during the 24 hours. The congestion of traffic and housing made it impossible to introduce three 8-hour shifts, as this would have necessitated a large addition to the number of workers. The arrangements for facilitating transport at Woolwich have been described in detail elsewhere.[5] All municipal duties at the Arsenal increased greatly with the increasing number of employees. Before the war few facilities existed for providing meals in the Arsenal. At the end of the war the total number of employees numbered some 100,000 and 72 dining rooms and short meal buildings had been

[1] Sec./Gen./802.
[2] Vol. V, Part III, p. 157 ; HIST. REC./R/1122.11/19.
[3] Employed on home work for the Arsenal.
[4] Vol. V, Part III, p. 157.
[5] Vol. V, Part V, p. 43.

provided.[1] The disposal of refuse and sanitary conditions generally involved a large increase in the duties of the Building Works Department.

(e) *The Nature and Quantity of the Factories' Work.*

The most striking feature about the output of the Woolwich Ordnance Factories during the war is the extraordinary diversity of the stores produced. Throughout the war the specialised skill and machinery of Woolwich were invaluable both for producing experimental and special types required in comparatively small quantities, and for meeting specially urgent demands. Plant was subject to constant changes to meet these demands, and continuity of output was almost unknown. Almost every kind of ammunition and its various components were manufactured at Woolwich, and the filling factories had to deal with the same variety of work, lyddite, T.N.T., fulminate of mercury, gun cotton, shellite, explosive for explosive bullets, and for a short time with gas shell. It was not unusual for the factories to have 300 items on the weekly programme, while 30 or 40 would be quite a large number for a national factory.[2] The Gun and Carriage Factories were at times dealing with 20 different types of guns. Woolwich programmes were also constantly liable to dislocation on account of the adjusting function which the Ordnance Factory performed in the general supply programme. Special instructions were constantly received to hasten certain orders in order to remedy a shortage. This continued throughout the war, but the adjusting process was specially imperative and frequent in the early years of the war before the supply of munitions was organised and co-ordinated. Experimental and special orders continued throughout the war, for Woolwich with its experienced staff and close touch with the Superintendent of Research, the Superintendent of Experiment, the Inspection Department, and Ordnance Committee was specially fitted for this work, and its concentration at Woolwich avoided dislocation in the national factories which were turning out stores in bulk on a repetition basis. Another special item in the Woolwich programme was the repair work done there. Damaged guns which required repairs of a difficult or intricate nature were subjected to special examination and report by the Chief Superintendent or his officers, and the experience gained was often of value in subsequent design.

Until the spring of 1915 all high-explosive shells were filled at Woolwich, and the greater part of this class of work was done there until April, 1916, when the national filling factories were in a position to begin output on a large scale. The output of complete small arms ammunition increased from about 28,750,000 in August-December, 1914, to 284,000,000 in 1915, and 418,000,000 in 1916[3] while the output of cartridges made by the trade and filled at Woolwich was about 803,000 during August-December, 1914, over 4,250,000 in 1915, and

[1] For a general account of the work in relation to welfare, *see* Vol. V, Part III, pp. 157-161.

[2] Sec./Gen./2239.

[3] Exclusive of Japanese and Russian ammunition and of ball ammunition.

9,000,000 in 1916. The Ministry remained dependent on Woolwich throughout the war for filling certain heavy gun shell and cartridges, and for all shell and complete rounds required for proof of fuses and practice, as well as for the bulk of ammunition required for anti-aircraft purposes, the filling of base percussion tubes and certain special primers and tubes; but at the end of the war Woolwich filled only about 7 or 8 per cent. of the total requirement of complete gun ammunition for the land service. On the other hand, the Admiralty depended on Woolwich for practically the whole of its filling during the war.[1]

During the first eighteen months of the war, the Woolwich output of shell and components represented a large percentage of the total. The output of empty shell increased from 124,562 in August to December, 1914, to 1,218,997 in 1915, and 1,749,577 in 1916, the output reaching a maximum in that year. The empty shell filled at Woolwich reached a maximum of 6,810,103 in the same year. At the end of the war the shell supply from Woolwich for land service was comparatively small. The cartridge case supply was 15 per cent. of the total, though in certain special natures it was 50 per cent. of the whole. For fuse manufacture Woolwich capacity was about 5 per cent. of the whole. Output was chiefly concentrated on Nos. 83 and 44, and in respect of these natures represented about 40 per cent. of the total capacity of the country.[2]

The gun programme at Woolwich, as regarded land service guns after 1916, was a very varying and diminishing one. The extent to which the Ministry relied on Woolwich for guns depended greatly upon Admiralty requirements, and it was often necessary for the Admiralty to absorb productive capacity normally available for land work, which then had to be transferred to other factories. The Admiralty had a preference for Woolwich, since their demands were usually of an urgent nature.[3] Moreover, practically all the new guns for the naval service were designed at Woolwich. Roughly, 75 per cent. of gun designs prepared at Woolwich were for the naval service, the remainder being divided between the land service and Royal Air Force. The total production of guns of all descriptions and for all services during the war was 4,326. The expansion during the first two years of war was very rapid. From August to December, 1914, 126 guns were produced, chiefly 6-in., 3-in. Q.F., 18-pdr., and 4·5-in. howitzer. The total figure for 1915 was 694, a large number of which were 18-pdr. and 4·5-in. howitzers. In 1916, 931 guns were produced, chiefly 60-pdr., 3-in., and 4·5-in. howitzers. A further great expansion took place in 1918, after the extension of the gun factory. The total production was 1,638, of which the greater number were quick-firing guns of various types. In addition to these guns a number of trench howitzers were produced during 1915 and 1916, and repairs and conversions accounted for the large total of 5,434. The miscellaneous productions of the Gun Factory formed a large item in its general production, and varied from important components such as breech

[1] C.R./Filling/384. [2] HIST. REC./R/1122.11/19. [3] *Ibid.*

blocks, pinions and aiming rifles to small parts such as springs, washers, keys and levers.

The production of the Carriage Department included, besides gun carriages and limbers, carts and wagons and travelling kitchens. The expansion during 1915 was enormous, the issues increasing from 1,388 during the last five months of 1914 to 7,769 in 1915. In 1916 the output of new carriages, etc., dropped to 4,939 and decreased during 1917 and 1918, the Carriage Department being largely occupied during 1917 and 1918 in repair work. The total of carriages, limbers, gun mountings, carts and wagons repaired in 1917 was 6,066, out of a total of 9,528 during the whole of the war period. The total of miscellaneous productions of the Carriage Department during the war period amounted to 8,985,925 items.

The tables of output which follow give some idea not only of the enormous quantity of the stores produced at Woolwich, but also of the extremely miscellaneous character of the work which was done there during the war.

TABLE I.

Issues from the Royal Gun Factory, Woolwich, August, 1914, to December, 1918.[1]

(*a*) ORDNANCE MANUFACTURED.

Description.	1914. Aug.–Dec.	1915.	1916.	1917.	1918.	Total.
Ordnance B.L. 15-in.	2	9	11	6	3	31
,, ,, 14-in.	—	—	—	2	—	2
,, ,, 13·5-in.	—	7	1	—	—	8
,, ,, 12-in.	—	—	3	1	—	4
,, ,, 9·2-in.	2	2	—	—	—	4
,, ,, 7·5-in.	—	—	—	8	1	9
,, ,, 6-in.	35	43	33	22	86	219
,, ,, 60-pdr.	—	88	168	—	46	302
,, ,, 4·7-in.	—	—	—	24	52	76
,, ,, 4-in.	—	1	14	9	—	24
,, ,, 2·75-in.	4	—	6	—	—	10
,, Q.F. 3-in.	26	46	182	160	333	747
,, ,, 4-in.	9	93	82	433	521	1,138
,, ,, 18-pdr.	11	177	12	—	180	380
,, ,, 13-pdr.	6	1	5	108	52	172
,, ,, 12-pdr.	1	8	76	62	265	412
,, ,, 6-pdr. (Sub. cal.)	—	30	17	3	—	50
,, ,, 3-pdr. (Vickers)	—	16	29	—	—	45
,, ,, 3-pdr. (Sub. cal.)	—	30	27	—	—	57
B.L. Howitzer 8-in.	—	—	—	20	—	20
,, 6-in. 26-cwt.	—	—	91	9	—	100
Q.F. ,, 4·5-in.	30	143	174	68	99	514
,, ,, 3·5-in.	—	—	—	2	—	2
Grand Total ..	126	694	931	937	1,638	4,326[2]

[1] Compiled from HIST. REC./H/1122·1/2, 3.

[2] Of these 4,168 were complete with breech fittings.

(*b*) TRENCH HOWITZERS MANUFACTURED.

Description.	1914. Aug.–Dec.	1915.	1916.	1917.	1918.	Total.
Ordnance R.M.L. Trench Howitzer 4-in.	12	50	238	—	—	300
Ordnance M.L. Trench Howitzer 3·7-in...	—	320	151	—	—	471
Ordnance R.M.L. Trench Howitzer 2-in.	—	126	2	—	—	128
Total	12	496	391	—	—	899

(*c*) ORDNANCE REPAIRED OR CONVERTED.

Description.	1914. Aug.–Dec.	1915.	1916.	1917.	1918.	Total.
Ordnance B.L. 15-in.	—	30	6	1	2	39
,, ,, 13·5-in.	3	18	6	8	1	36
,, ,, 12-in.	20	27	21	16	17	101
,, ,, 9·2-in.	4	7	25	23	14	73
,, ,, 7·5-in.	—	1	3	1	1	6
,, ,, 6-in.	56	85	46	80	70	337
,, ,, 6-in. converted to 8-in. How.	—	24	—	—	—	24
Ordnance B.L. 4-in.	8	11	4	53	2	78
,, ,, 60-pdr.	2	25	96	228	144	495
,, B.L.C. 15-pdr.	5	14	25	3	6	53
,, B.L. 12-pdr. 6-cwt. ..	—	5	—	1	—	6
,, B.L. 2·75-in. ..	—	—	2	—	—	2
,, ,, 10-pdr. .. (jointed).	2	2	3	1	—	8
,, ,, 9·2-in. How.	1	—	1	—	—	2
,, ,, 8-in. ,,	—	1	—	27	1	29
,, ,, 6-in. 30-cwt. ,,	26	60	21	16	—	123
,, ,, 6-in. 26-cwt. ,,	—	—	—	42	8	50
,, ,, 5-in. ,,	6	20	33	1	—	60
,, Q.F. 6-in. ..	1	11	34	1	1	48
,, ,, 4·7-in. ..	104	193	211	68	20	596
,, ,, 4-in. ..	60	26	14	4	8	112
,, ,, 3-in. ..	—	—	1	23	48	72
,, ,, 18-pdr. ..	18	7	203	1,028	318	1,574
,, ,, 15-pdr. ..	10	40	4	2	—	56
,, ,, 13-pdr. 9-cwt	—	—	1	166	130	297
,, ,, 13-pdr. ..	6	64	80	33	18	201
,, ,, 12-pdr. 18-cwt	—	—	—	3	—	3
,, ,, 12-pdr. 12-cwt	4	15	76	11	6	112
,, ,, 12-pdr. 8-cwt	2	5	3	—	—	10
,, ,, 4·5-in. How.	29	1	16	113	5	164
,, ,, 6-pdr. .. (Hotchkiss)	8	24	63	6	—	101
,, ,, 3-pdr. .. (Hotchkiss)	8	17	60	8	11	105
,, ,, 6-pdr. .. (Nordenfeldt)	—	54	11	42	5	112
Carried forward ..	383	787	1070	2009	876	5085

ORDNANCE REPAIRED OR CONVERTED—*cont.*

Description.	1914. Aug.–Dec.	1915.	1916.	1917.	1918.	Total.
Brought forward ..	383	787	1070	2009	876	5085
Ordnance,						
Q.F. 3-pdr. .. (Nordenfeldt)	—	2	—	—	—	2
,, ,, 6-pdr. .. (single tube)	—	—	4	1	5	10
,, ,, 6-pdr. .. (Sub. cal.)	1	28	38	29	15	111
,, ,, 3-pdr. .. (Sub. cal.)	1	41	11	16	7	76
,, ,, 3-pdr. .. (Vickers)	2	5	8	2	—	17
,, ,, 77-mm. ..	—	—	—	16	46	62
Total	387	863	1,131	2,073	909	5,363

(*d*) TRENCH HOWITZERS REPAIRED OR CONVERTED.

Description.	1914. Aug.–Dec.	1915.	1916.	1917.	1918.	Total.
Trench Howitzer, 4-in.	—	2	—	—	—	2
,, ,, 3·7-in.	—	56	4	2	—	62
,, ,, 240-mm.	—	—	—	4	—	4
Total	—	58	4	6	—	68

(*e*) MISCELLANEOUS PRODUCTION.

Gun and Howitzer Fittings.

Component parts, important items, viz. :—breech blocks ; carriers ; frames, breech mechanism ; pinions, intermediate and crank ; rifles, aiming ; screws, breech ; vents, axial 4,899

Component parts of minor importance, viz. :—actions ; arcs, control ; attachments ; bearings, ball ; blocks (various) ; bolts (various) ; boxes (various) ; brackets (various) ; buffers ; bushes (various); catches (various); clamps ; collars (various) ; counterweights ; cranks (various) ; cutters; cylinders, anti-fouling ; discs (various) ; extractors (various) ; firing mechanisms ; firing pieces ; frames (various) ; gear, hand operating ; guides (various) ; hammers, firing ; hard steel pieces ; keys (various) ; latches (various) ; lever shafts ; levers (various) ; links (various) ; lubricators ; needles (various) ; nuts (various) ; obturators (various) ; pads (various) ; pieces, filling (various) ; pinions (various) ; percussion firing gears (various) ; plates (various) ; rings (various) ; plugs ; plungers ; screws ; sights (various) ; sleeves (various) ; sockets (various) ; spindles (various) ; springs (various); stirrups, hammer firing; stops, safety (various) ; strikers (various) ; studs ; tappets, lever trigger ; toe pieces for locks ; tommies (various) ; triggers (various) ; vents (various) ; washers (various) ; wedges (various) ; wires (various) 177,925

Forgings, castings and stampings in connection with the above .. 8,052

Implements, Gauges and Accessories.

Adapters (various); apparatus, testing; bits, vent; blocks (various); borers, tube chamber; boxes (various); breech mechanisms; bushes; cases (various); clamps; clearers, vent; cutters; cutters and punches; discs; drifts (various); gauges (various); guides; hammers, lead; instruments, taking impressions bore; machines (various); presses, obturator; rimers, breech; rods, measuring; scrapers, ordnance; sectors; springs, gauges crusher; tools (various); wrenches (various)	37,348
Castings and forgings in connection with implements, gauges and accessories	131

Heavy Forgings.

"A" tubes, Q.F. 4·7 in.; jackets, Q.F., 18-pdr.; short bores and chamber liners, Q.F., 18-pdr. and 13-pdr. Q.F. 4·7-in., B.L. 60-pdr.; inner "A" tubes, B.L. 60-pdr., B.L. 6-in.; "A" tubes, Q.F. 18-pdr. and 13-pdr., B.L. 6-in., B.L. 8-in. How.; short bores and chamber liners, B.L. 6-in.; Q.F. 3-in. Q.F. 12-pdr.; inner "A" tubes, B.L. 6-in.; inner "A" tubes, B.L. 4-in.; inner "A" tubes, B.L. 12-in.; inner "A" tubes, B.L. 9·2-in.; jackets Q.F. 3·7-in. How.; jackets Q.F. 4·5-in. How.; "A" tubes, Q.F. 3·7-in. How. (muzzle and breech), Q.F. 4·5-in. How. Q.F. 3-in.	1,819
Wireless Telegraphy parts of	7,526

Operations for Contractors.

Jackets Q.F. 18-pdr. rough turned, rough bored and machined; treating forgings for inner "A" tubes B.L. 9·2-in. supplied by contractors; treating steel forgings for Q.F. 6-pdr. wedges blocks	185

Accessories supplied to French Government and to various Firms.

Completing forgings of discs, breech, rifle, aiming, from the Anglo-Russian Engineering Company; making and supplying jigs and gauges to guide manufacture of obturators; and making and supplying for French Government obturators (various) and discs, adjusting	1,420
Total	239,305

In addition to the above the following very small accessory articles were made during the same period :—

Coppers, gauges (various)	1,000,890

(*f*) MISCELLANEOUS REPAIRS.

Repairs to component parts of Breech Fittings, etc., viz. :—Blocks, breech; boxes; carriers; locks, electric; mechanisms; obturators; rings; screws, breech; sights; strikers; vents	11,679
Repairs to Aiming Rifles and Morris Tubes	910
Forgings, viz. :—Breech rings; jackets; inner tubes; liners	461
Total Items	13,050

TABLE II.

Issues from the Royal Carriage Department, Woolwich, August, 1914, to December, 1918.[1]

(*a*) CARRIAGES, LIMBERS, GUN MOUNTINGS, CARTS AND WAGONS MANUFACTURED.

Description.	1914. Aug.–Dec.	1915.	1916.	1917.	1918.	Total.
Carriages, Field, Siege and Travelling (various) for Guns from B.L. 2·75-in. to B.L. 8-in. How.	88	504	336	225	228	1,381
Carriages, Garrison (various) for Guns from Q.F. 4-in. to B.L. 9·2-in.	—	2	17	1	4	24
Carriages, Naval	—	—	129	182	447	758
Carriages, Proof	2	—	—	—	—	2
Limbers, Carriage (various) for Guns from Q.F. 13-pdr. to B.L. 8-in. How.	64	2,047	1,620	1,588	1,253	6,572
Gun Mountings for Guns from Machine-gun ·303-in. to Q.F. 13-pdr.	196	442	214	243	529	1,624
Carts (various) including Kitchens	490	1,432	394	133	358	2,807
Wagons (various)	548	3,342	2,229	1,027	693	7,839
Total	1,388	7,769	4,939	3,399	3,512	21,007

(*b*) CARRIAGES, LIMBERS, GUN MOUNTINGS, CARTS AND WAGONS REPAIRED.

Description.	1914. Aug.–Dec.	1915.	1916.	1917.	1918.	Total.
Carriages, Field, Siege and Travelling for Guns from Q.F. 1-pdr. to B.L. 8-in. How.	136	191	86	273	310	996
Carriages, Garrison, for Guns from Q.F. 6-pdr. to B.L. 6-in.	22	51	66	46	36	221
Limbers for Guns from Q.F. 1-pdr. to 9·45-in. How.	187	213	84	277	108	869
Mountings from tripod for Guns from Machine-gun ·303-in. to 3-in. H.A.	45	30	41	5,014	1,211	6,341
Carts (various)	31	63	2	31	123	250
Wagons (various)	163	119	60	425	84	851
Total	584	667	339	6,066	1,872	9,528

[1] Compiled from HIST REC. /H/1122.1/2, 3

(*c*) MISCELLANEOUS ARTICLES MADE.

Major items, viz. :—adapters (various) ; axle trees (various) ; beds for trench howitzers ; buffers (various) ; capstans, crab ; cradles (various) ; drugs (various) ; frames, crab, for hoisting guns 50 and 25 tons ; gear for correcting automatic sights ; gyns, triangle ; holdfasts (various) ; loading teachers (various) ; lorries, aeroplane ; pedestals, carriage ; platforms, travelling and firing ; pumps, air or liquid ; recuperators ; screens for velocity experiments ; sleighs, gun	2,441
Minor items, viz. :—adapters, cradle ; apparatus, adjusting and testing (various) ; arcs, traversing ; attachments ; axles ; bags (various) ; banderols ; bandoliers ; bands, canvas (various) ; barrows (various); bases, pole for tents, marquee ; baskets, ammunition (various) ; battens ; baulks ; beams ; bearers (various) ; blocks (various) ; boards (various) ; brushes (various) ; buckets (various) ; buoys ; bushes (various) ; buttons, wood, tent ; calculators, range ; cans (various) ; caps (various) ; carriers (various) ; cartouches ; catches ; chesses, pontoon ; clamps ; cleaners (various) ; clinometers ; coatings ; connectors ; correctors ; couplings, pontoon ; cradles ; camp kettles ; cylinders (various) ; davits ; derricks ; discs ; drifts ; drivers ; drums, iron and wood ; ejectors, projectile ; eyes, lifting ; extractors (various) ; felloes, sand ; fittings (various) ; frames ; funnels (various) ; gauges (various) ; gear, clamping ; grabs ; gunwales, pontoon ; handles (various) ; handspikes (various) ; heads (various) ; holdalls ; holders ; holdfasts ; hooks ; indicators (various) ; jacks ; kegs, paint (various) ; levers (various) ; lids ; lifters ; mallets (various) ; measures ; panniers ; pickets ; pipes ; pistol grips ; planks (various) ; plates ; plotters ; pockets ; pumps ; racks ; rammers (various) ; rectifiers ; reflectors ; ribands ; ribs, pontoon ; rings ; rods (various) ; rollers (various) ; ropes (various) ; rowlocks, pontoon ; rules (various) ; runners ; saddles (various) ; screw-drivers ; scotches (various) ; selvagees ; setters ; shafts (various) ; spars ; shields (various) ; shoes (various) ; sights, fore, tangent and telescopic ; slings (various) ; spanners ; sponges ; stanchions ; stands, portable for machine guns in torpedo boat destroyers ; staves (various) ; sticks ; straps ; swingletrees ; syringes ; tools ; trailers ; tampeons ; tanks, oil ; transoms ; trays (various) ; targets ; trestles ; trolleys ; uprights for firing sound pockets ; vases, tent ; washers ; wedges ; wrenches	1,292,841
Aprons, bags, covers (various), and hoods	66,480
Barrels (various), and kegs	22,336
Boxes (various)	1,085,943
Cases (various)	464,860
Chests (various)	14,171
Labels, line (various)	3,552,553
Pegs, picketing with rope loop	331,940
Packing pieces (various)	988,323
Pins, lynch (various)	17,773
Pins, tent	523,700
Plugs (various)	321,639
Poles, posts and props	268,603
Sights (various), including automatic and naval	7,593
Skids (various)	9,052
Wheels (various)	15,677
Total	8,985,925

(*d*) MISCELLANEOUS ARTICLES REPAIRED.

Barrels, powder ; boxes (various) ; cases (various) ; chests ; dischargers, grenade ; felloes ; gauges ; indicators, fuse ; jacks, lifting ; motor chassis ; packsaddlery ; pedestals, carriage ; platforms ; plugs ; sights (various) ; slugs, projectile ; wheels	4,318,205

TABLE III.

Issues from the Royal Laboratory, Woolwich, August, 1914, to December, 1918.[1]

(*a*) ANNUAL OUTPUT OF PRINCIPAL STORES.

Description.	1914. Aug. to Dec.	1915.	1916.	1917.	1918.	Total.
Bombs (various), complete—						
Manufactured and Filled	1,913	20,349	30,868	18,456	2,872	74,458
Filled only	—	3,879	28,134	31,545	82,810	146,368
Cartridges—						
Q.F. 3-in. to 4·7-in.—						
Manufactured and Filled	11,939	11,878	138,279	260	27,032	189,388
Filled only	802,990	4,341,608	9,064,342	14,141,415	10,343,872	38,694,227
Drill, Q.F. 18-pdr. to 6 in.	626	17,223	11,625	3,678	5,195	38,347
Gun, B.L., R.M.L. and S.B. 3-pdr. to 14-in., filled	127,602	738,657	1,350,645	2,096,295	2,924,390	7,237,589
Small Arm— (Short, Rifle Grenade, Tracer, Armour-piercing Buckingham), complete	28,783,300	284,009,747	418,000,896	298,384,943	347,348,776	1,376,527,662
·303 Ball, complete ..	1,440,205	2,613,695	1,042,241	4,007,280	3,732,518	12,835,939
Pistol, Webley, Ball ..	—	—	83,191,538	79,738,562	—	162,930,100
Japanese	—	—	155,400	24,495,508	16,192,117	40,843,025
Russian	—	—	4,000	125,320,902	351,600	125,676,502
Impulse, Torpedo, complete	—	17,800	12,524	20,547	26,692	77,563
Fuses—						
Manufactured and Filled	219,010	1,085,422	2,228,174	3,456,621	975,216	7,964,443
Empty	—	—	—	331,283	3,036,962	3,368,245
Filled only	—	960,678	16,002,975	19,482,924	14,840,339	51,286,916
Shells—						
Empty	124,562	1,218,997	1,749,577	1,536,942	1,217,327	5,847,405
Filled only	233,207	2,094,379	6,810,103	6,181,377	4,591,248	19,910,314
Drill	21	261	25	90	1,221	1,618
Dummy	64	1,208	109	193	82	1,656
Star-Shells, Filled only ..	—	294	86	5,879	34,284	40,543
Trench Howitzer Ammunition—						
Bombs	545	189,515	156,652	5,388	—	352,100
Charges	—	30,743	25,584	31,852	—	88,179
Components	—	308,713	32,261	804	—	341,778
Totals ..	31,745,984	297,665,046	540,036,038	579,292,744	405,734,553	1,854,474,365

[1] Compiled from HIST. REC./H/1122·1/1.

(*b*) AGGREGATE OUTPUT OF SECONDARY STORES.

Description.	Total during the War.
Components, Bomb—	
Manufactured	1,072,267
Filled only	725,673
Components, Cartridge—	
Q.F. Manufactured	927,215
B.L. Manufactured	128,727
B.L. Filled only	133,526
Components, Shell—	
Adapters; bags, burster; bags, primer; bandoliers, cotton; caps, false, steel; flash reducing charges for 4·5-in. How.; gaines.	30,675,878
Components for Shell Filling	732,480
Detonators	1,725,370
Exploders	8,384,991
Mines—	
Empty	429
Filled	41,996
Sweeping Charges	10,863
Depth Charges (Filled only)	6,566
Counter Mines (Filled only)	64
Shot—	
Proof 1-pdr. to 15-in.	13,194
Case, 6-pdr.	1,997
Practice, 2-pdr. to 13·5-in.	46,931
Paper, 4·7-in. and 12-pdr.	520
Tracers, Shell, Night, External and Internal—	
Manufactured and Filled	739,337
Filled only	343,821
Dummy	28,157
Composition for Bullets (in lbs.)	135,438⅜
Cement, various (in lbs.)	177,265¾
Match, quick (in yds.)	2,162

(*c*) MISCELLANEOUS ARTICLES MANUFACTURED.

Bags, primer, filled belt; cases, guncotton; cases, powder; components of cases; components of exploders; components of fuses; components of S.A. cartridges; components of mines; containers, copper and aluminium; copper gauges; covers, cartridge; cushions, powder barrel; cylinders, guncotton; discs for lyddite shells; driving-bands; extractors (various); fuses, converted; fuses fitted with gaines; guncotton, wet, charges; igniters, torpedo (filled only); implements, ammunition; lanyards; levers; lights; links, belt M.G.; litmus paper; machines, rocket; machines for weighing cartridges; mouthpieces for cylinders, G.C.; pieces, packing, copper, for boxes, guncotton; plates; plugs; pockets; portfires; primers; protectors; parachutes for star-shells; puffs, cordite and powder; pumps, air; rectifiers, guncotton, primers; rings, augmenting; rockets; screws; shot, rear for Davis gun; sockets; strips, augmenting; spanners; torpedo warheads, charges (various); tubes (various), made and filled, empty, filled only; tubes, electric, wireless, for torpedo dropping gear .. 297,525,977

(*d*) REPAIRS.

Description.	Total during the War.
Naval Ordnance Stores—	
Bombs, all patterns	12,530
Cartridges :	
B.L. 4-in. to 15-in.	3,636
Q.F. 1-pdr. to 6-in.	382,927
Q.F. Cases	3,310,099
Cases, powder	156,708
Shell, all patterns	70,965
Land Service Stores—	
Bombs, and Bombs Carcass	5,545
Cartridges :	
B.L. Filled	138,406
R.M.L. and B.L. (Filled) examined, broken down, etc.	100,504
Q.F. Empty	1,069,945
Q.F. (Filled) broken down and re-made	2,922,950
Q.F. Cases, empty	3,101,001
Q.F. or Q.F.C. Adapters	1,466,355
Cylinders, cartridge	494,069
Plugs	4,235,439
Primers :	
Percussion, etc.	1,487,990
Electric, Large, etc.	16,975
Shell, empty, 1-pdr. to 15-in.	340,448
Miscellaneous Repairs	2,789,860

III.—The Royal Small Arms Factory, Enfield Lock.

(a) *Preliminary.*

The Royal Small Arms Factory at Enfield was established in 1804, when the country was threatened with invasion and the Government was almost entirely dependent on foreign muskets for arming the regular troops and the volunteers. Until 1854 the establishment was on a very restricted basis, and was occupied mainly with such work as the conversion of the flint-lock to the percussion musket, the manufacture of swords, repairs and the "setting-up" or assembling of a comparatively small proportion of the musket parts, for which contracts were placed in industrial districts. In that year a very considerable extension was made for the manufacture of rifles by machinery. The extension was the outcome of delay experienced in obtaining the new Minié rifle from the trade during the year 1853. The Master-General of the Ordnance (Lord Raglan) accordingly planned the establishment of a large government rifle factory to provide the whole of the British forces, independently of the trade. This factory was to have been erected at Woolwich and to have replaced the outlying establishments at Birmingham, Enfield and the Tower, where certain operations in the manufacture or repair of muskets were then being carried out. At the

recommendation of a select committee, which considered the cheapest and most efficient method of making small arms, this larger project was modified and a comparatively small factory was built at Enfield to serve as an experiment in the advantages to be derived from the more extensive application of machinery, as a check upon contractors' prices and as a resource in time of emergency.

The new rifle factory was complete by 1858, and consisted of two main divisions, the smithery, having about 45 forges, and the department for rolling and perfecting the rifle barrels. Each division had its own power unit, the one of 80 h.p., the other of 25 h.p. These were supplementary to the water power for which the site had originally been chosen. A large proportion of the machinery, especially that used for the gunstocks, was brought from the United States, and the whole factory was the result of a careful study of the methods used in the national musket factories in Belgium and America.[1]

(b) *Manufacturing Programme.*

At the outbreak of the European War, the Royal Small Arms Factory was chiefly engaged in the manufacture of S.M.L.E. rifles, but it was also responsible for producing certain accessories such as bayonets, scabbards, cavalry swords and chargers; for the resighting of rifles for Mark VII. ammunition; the supply of spares for the Chief Ordnance Officer at Weedon; repairs to rifles and to certain machine guns. Experimental work was undertaken to a certain extent and, during the war, some special work, such as the determination of the amount of phosphorus and sulphur permissible in certain classes of steel.[2]

Since 1912 all requirements for rifles for Home Service had been met from Enfield, and the average annual output of the newest type of rifle for current equipment was 25,279[3] with a certain number for replacement of stock. The theoretical output on a two-shift capacity was 4,200 rifles a week,[4] and the actual output immediately prior to to the war was 1,000 new and about 1,000 repaired rifles weekly, while of accessories 600 bayonets, 700 scabbards and 50 cavalry swords were made per week.[5]

Output of all arms increased rapidly on the declaration of war. By September, 1915, 6,000 complete rifles were turned out weekly, repairs averaged about 6,000 a week, and a good deal of work was done in the provision of locks and spare parts for machine guns. In addition, up to December, 1915, a total of 51 Maxim guns were made. The manufacture of accessories had similarly increased; for instance, in June, 1915, scabbards were produced at the rate of 4,900 per week, but the supply of rifles to be resighted had come to an end.[6]

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[1] *Evidence and Report of Select Committee on Small Arms*, 1854; J. Tuff, *Historical Notices of Enfield* (1858).
[2] D.D.G.E./E.M. 4/325.
[3] Hist. Rec./H/170/5.
[4] Sec./RS/135B1.
[5] O.F./Gen./039.
[6] Hist. Rec./R/1122.1/4; O.F./Gen./039; D.D.G.E./E.M.1/41.

With the development of the "peddled scheme"[1] of rifle manufacture in the autumn of 1915 and the first few months of 1916, the manufacture of bayonets, which had reached 6,000 weekly by October, 1915, was entirely entrusted to the trade and the capacity so released was devoted to the production of rifle bodies. For the assembling of rifles made from these and other bodies manufactured outside the factory, and from components turned out by the trade, a special shop was erected at Enfield. In January, 1916, the scope of the scheme was enlarged by the formation at Enfield of a rifle component pool into which were put all the surplus components made by the rifle factories, all parts produced by component manufacturers and the output of bodies for peddled rifles.

After 1916[2] the demand for cavalry swords and chargers fell off. Output had reached 900 and 500,000 per week respectively, but by September, 1917, this work, except for repairs, had entirely ceased. At the end of 1917 it appeared advisable to reduce the output of rifles as demands were being more than met, and early in 1918 it was arranged to stop the manufacture of peddled rifles; but owing to the demand for machine gun parts, which could best be produced at Enfield, it was decided to continue the peddled scheme at its maximum output and by reducing the output of Enfield-made rifles to devote the extra capacity to the manufacture of machine gun parts in addition to the repair work on Lewis guns which the Superintendent had recently undertaken.[3] This programme was interrupted by the increase in rifle requirements put forward in April 1918,[4] and the factory again worked up practically to its maximum output at the expense of the machine gun scheme. During the autumn of 1918 the output was again reduced and decreasing rapidly after the signing of the Armistice was, by January, 1919 about 36 per cent. of the October, 1918 average. In 1919 it was decided to stop the production of new weapons, to retain sufficient material to assemble 100,000 rifles[5] and to employ the staff on repair work only.

(c) *Administration.*

For purposes of administration, the Royal Small Arms Factory and the Royal Gunpowder Factory at Waltham were, for the first two years of the war, united under the charge of one Superintendent, Colonel F. T. Fisher, who was directly responsible when war broke out to the Master-General of the Ordnance, except for questions relating to finance and accounts, which were referred to the Chief Superintendent of Ordnance Factories. The Assistant Superintendent at Enfield was Major S. C. Halse, and there were in addition to the technical staff a Building Works Department and a Common Services Branch which was shared with the Royal Gunpowder Factory. The central office was at Enfield and the factory was also the headquarters of the Chief Inspector of Small Arms.

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[1] Vol. XI, Part IV, Chaps. II, III, V.
[2] Vol. XI, Part IV, Chap. III.
[3] D.D.G.E./E.M.4/330.
[4] D.D.G.E./E.M.4/406.
[5] 77/Gen. No./4785.

On the formation of the Ministry of Munitions, Colonel Fisher and Major Halse, while acting as technical advisers to the Ministry, continued to report to the Master-General of the Ordnance,[1] but in August, 1915, when the Ordnance Factories were taken over by the Ministry, the administration of Enfield was dealt with by a branch known as C.M.7. in the Department of the Director-General of Munitions Supply.

In January 1916 the two factories were divided for the purposes of departmental control[2] and were attached for administrative purposes to the units of the Ministry concerned with the stores which they respectively manufactured, Enfield being dealt with by a branch known as E.M.4 in the Department of the Director-General of Ordnance Supplies. From the point of view of finance and accounts, the Ordnance Factories continued to form a single concern and the central office at Enfield was retained. At the same time Colonel Halse, who was also engaged on part time duty at the headquarters of the Ministry, was appointed Deputy Superintendent with full responsibility to Colonel Fisher for the manufacturing output of the factory.[3] In May, 1917, Colonel Halse gave up his duties at Enfield,[4] and in December, 1917, on the resignation of Colonel Fisher, Enfield was separated from Waltham, the common services staff were divided and Colonel C. I. Newton appointed as Superintendent of Enfield.[5]

During the war several variations in the normal procedure were allowed. For instance, in certain ways the Superintendent was given greater powers. In normal times requisitions for machinery were dealt with from headquarters, but soon after the outbreak of war the Superintendent was permitted to purchase urgently needed machines "over the counter."[6] Again shortly after the beginning of hostilities he was ordered by the Master-General of the Ordnance to undertake the provision of timber for trade-made rifles as well as for the factory's output.[7]

Normally, expenditure for the ensuing year was approved beforehand, and an allotment made to the Superintendent of a sum sufficient to cover maintenance and minor unforeseen expenses. During the war the rapid increase in the cost of labour and material and the expansion of the factory made accurate forecasting a matter of impossibility and additional allotments in the course of the year were frequently required.[8] No new services above £200 in cost were put in hand without special authority. Building services were usually opened to competitive tender, but in many instances the factory workmen were employed without recourse to the open market.

(d) *Factory Expansion.*

The position of the Royal Small Arms Factory on the way to the coast, in a flat country liable to heavy floods with but little accommodation for other than the permanent staff, and practically no building

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[1] D.D.G.E./E.M.1/40.
[2] Office Instruction No. 87.
[3] D.G.O.S./Enf./17.
[4] Departmental Office Notice, No. 36.
[5] C.R./DGSG/2512.
[6] 77/Gen. No./4757.
[7] OF/Gen./039.
[8] D.D.G.E./E.M.4/94; O.F./Bldgs/55.

land available, with other large factories in the neighbourhood, and at a distance from the supply of coal, iron and steel, was as bad a site as could well be conceived for the production of more than half the available rifle supply; although it had originally been chosen in view of its waterways. Nevertheless the difficulties of rifle manufacture were such that it was impracticable to start up new factories,[1] and as the possibilities of extending the trade rifle factories were limited, it became necessary, when the contracts placed in America failed to produce the deliveries required, to depend for the increased supply largely upon extensions made to the Enfield shops. Moreover, the success of the peddled scheme depended primarily on the soundness and reliability of the organisation which was to test and assemble the parts. This need Enfield was best able to supply.

Sanction for the extension of the plant to a capacity of 5,750 rifles a week was given in October, 1914[2] but subsequent proposals to double or largely extend the place were rejected on account of the difficulties involved. From time to time, however, additional machinery was acquired as for instance from the Standard Small Arms Company in 1916,[3] and in addition, a number of shop extensions were made, especially in connection with the development of the peddled scheme. By June 1917 in addition to the extension of the bayonet plant[4] and the erection of a new assembling shop, the Superintendent reported progress with a new barrel mill, a new stocking shop, a new automatic screw shop, a repair shop, browning shop, machine gun shop, oil store, stores for gun stocks and new accommodation for the clerical staff. The supply of gas and electricity was supplemented by power from local bodies.[5]

The introduction of female labour necessitated provision of special facilities such as a canteen and rest and recreation rooms. Ingress and egress were rendered somewhat easier by new bridges over the water. The handling of so much material presented special difficulties and at times the congestion was serious. Trucks were left for some days under load.[6]

To expedite matters, various improvements were made, such as the extension of a railway siding into the factory, a development which proved of inestimable value,[7] and the laying of a new road for heavy cart traffic.[8] Considerable use was made of the waterways, and a helpful remedy was found in the employment of petrol lorries and the diversion of stores intended exclusively for the Royal Gunpowder Factory to another station.[9]

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[1] *See* Vol. XI, Part IV, Chap. V.
[2] OF/Gen./039; 77/Gen. No./4757.
[3] *See* Vol. XI, Part IV, Chap. II.
[4] Converted in 1916 to a body-making shop. *See* above, p. 30.
[5] D.G.O.S./Enf/23; D.G.I.M./Bldgs./213; D.D.G.E./E.M.4/93. For other extensions, *see* D.D.G.E./E.M. 4/247, 115, 100; O.F./Bldgs/038; Hist. Rec./R/1122.1/3.
[6] D.D.G.E./E.M.4/61.
[7] Hist. Rec./R/1122.1/3; D.D.G.E./E.M. 4/114.
[8] Approved 13.3.16. D.D.G.E./E.M. 4/57.
[9] Hist. Rec./R/1420/21; D.D.G.E./E.M. 4/2.

(e) *Labour.*

The labour difficulties prevalent everywhere were at Enfield accentuated by the unsuitable location of the factory. For instance, the proposal in March, 1915, to double the output of the factory was abandoned largely because the labour available in the district was almost used up and it was impracticable to bring in a large amount of outside labour when there was no accommodation for billeting workmen, nor any chance of a successful housing scheme.[1] Nevertheless, there was a very large gradual increase in staff and long distances had to be traversed. A limited attempt to minimise the ill effects of fatigue was made in the provision of a hostel for women,[2] and there were rest rooms and clubs in the precincts of the factory. Various concessions in the rules were also made for the benefit of workers. A fair number of boys were employed, but by March, 1915, the supply was poor owing to the high wages offered in local factories. In May, 1916, they were 10 per cent. of the total strength and in May, 1918, 6 per cent.[3] In the early months of 1916, dilution by women was thoroughly discussed and in April 51 women were engaged on unskilled work. The constantly increasing demand for arms severely militated against the substitution of women for men as a matter of pure dilution and the highly specialised nature of much of the work limited their number. Nevertheless, by May, 1918, there was a certain number in all departments[4] and as a result of an investigation by the dilution officer, the training of women on more specialised work, not hitherto attempted by them was projected.[5] The employment of volunteers also tended to lessen the problem. In September, 1915, there was a considerable number at work on Sundays and at the end of October, 1918, there were 265 in the factory.[6] The quality of labour obtainable, however, had a somewhat adverse effect on the work and in June, 1917, the Superintendent complained of the reduced output obtained from the older men, and of the large number of men who were found to be physically incapable of the work,[7] while the poor quality of some of the peddled components necessitated the employment of additional labour.

On March 3, 1916, the Royal Small Arms Factory was declared a controlled establishment. The chief result of this step in respect of the factory was that trade union customs which tended to restrict production were suspended and that the breaking of shop rules became an offence under the Act.[8]

The years 1917 and 1918 proved specially difficult. The abolition of the leaving certificate resulted in the loss of 132 skilled men and in the spring of 1918 the position became really serious. Many men were lost to other factories where special inducements were offered, and

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[1] 94/R/14.
[2] Approved 11.10.16 ; D.D.G.E./E.M. 4/117.
[3] 94/R/14 ; D.D.G.E./E.M. 4/118 ; C.E. 1949/3.
[4] The percentage of the total staff was 15·3 per cent.
[5] C.E. 1949/12, 3 ; D.D.G.E./E.M. 4/42, 58 ; D.G.O.S./Enf./23.
[6] D.D.G.E./E.M. 4/554.
[7] D.G.O.S./Enf./23.
[8] D.D.G.E./E.M. 4/46.

by May, 1918, urgent machine gun repairs had to be reduced for lack of labour.[1] Gaugemakers especially were difficult to obtain and as Enfield supplied all standards and check guns for the manufacture of rifles to various firms throughout the country and in India, there was cause for real anxiety. Semi-skilled labour was indeed obtained from the training schools, but the period and quality of training were not sufficient to produce the highly skilled workmen who were so essential in successful rifle production. The Superintendent further suffered loss of expert staff such as the transfer of Colonel Halse to the head-quarters of the Mininstry, and the loan of special staff to the rifle factories in the United States.

The following numbers give some indication of the increase in staff during the war. In July, 1914, about 1,800 men and boys were employed. By October the number was 4,210 increasing to 4,848 in December, 1914. In April, 1916, the total number including 51 women was 7,754 and in October, 1917, there were 7,707 men, 863 boys, 1,438 women and 106 girls. At the end of April, 1918, there were 9,554 persons employed of whom 7,300 were men, 777 boys, 1,404 women and 73 girls.[2] Office staff, although it increased considerably, formed only a small percentage of the total numbers employed. In 1918 the salary and wages bill including war bonuses approximated to £3,000,000.[3] After the signing of the Armistice the staff was rapidly reduced and it was arranged that by March 31, 1919, the men were to be at the peace strength of 1,800 and all women were to be discharged by January, 1919.[4]

(f) *Output.*

Demands were issued by means of extracts for 100,000 rifles at a time ; the stores branch at the factory ordering material as soon as the extract was received and issuing appropriate quantities to the various shops.

In addition to material required for the supply of factory-made rifles, the Superintendent purchased and issued all wood used by trade rifle and component manufacturers. For this purpose walnut was the only satisfactory wood, and when, soon after the outbreak of war, European supplies failed and the small stocks in Great Britain were exhausted, America became the only source of supply. The regular shipment of sufficient quantities was a constant anxiety. Moreover, as a large amount of the American timber was purchased in plank, it was necessary to instal saw mills and to train a special staff of tracers and viewers.[5] To minimise risks from fire the wood was stored in specially constructed buildings and where possible, distributed in local maltings hired for the purpose, but it was very difficult to secure a large reserve.[6]

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[1] C.E. 1949/3 ; D.D.G.E./E.M. 4/437.
[2] D.G.O.S./Enf./23 ; C.E. 1949/13.
[3] Higher Staff, £6,544 and £209 war bonus ; Factory Staff, £2,332,501 plus £719,715 war bonus ; Clerks £27,841 and £7,882 war bonus (D.D.G.E./E.M.4/353).
[4] D.D.G.E./E.M. 4/631.
[5] O.F./Gen./039.
[6] D.D.G.E./E.M. 4/126 ; D.G.O.S./Enf./23.

The rifle making factories purchased their own steel, but at the outset of the peddled scheme, the Superintendent, to help contractors who desired it, supplied steel from Enfield, at first free, but later on repayment. By 1918 all steel for the rifle component pool contractors was issued by the Superintendent.[1]

The earliest deliveries under the peddled scheme did not begin until July 1916, but when the scheme was in full working order, it was estimated that 8,500 complete rifles were made weekly in the factory from factory-produced components, and the remainder were regarded as peddled rifles. Of these up to 10,000 rifles weekly were turned out with but little help from the component pool, but all in excess of this number were almost entirely made from peddled components. During the period of the war the output of the factory was as follows :—[2]

	1914. Aug. to Dec.	1915.	1916.	1917.	1918.	Total.
Rifles, S.M.L.E. ..	63,107	253,545	413,424	618,073	659,423	2,007,572
Machine Guns, Maxim ..	13	38	307	308	—	666

In addition to complete machine guns, 130,326 barrels[3] for guns of various types were made and 6,566 locks. Other parts and accessories for machine guns were of an exceedingly miscellaneous nature.[4]

In all, they amounted to over 1,000,000 articles, of which 506,000 were ammunition belts of different kinds, 172,000 tin boxes, and 119,000 mirror reflectors. Most of these were intended for Maxim guns, but a good deal of work for Vickers guns was done. Repairs were undertaken on 600 Maxim, 6,900 Vickers and 260 Lewis guns. In addition to complete rifles made from factory or peddled stock, approximately 425,000 bayonets, 52,000 cavalry swords, and 1,500,000 scabbards were manufactured. Rifle parts and accessories were also produced in great diversity, making a total of about 65,000,000 of which 5,500,000 were pull-throughs, 356,000 wooden components, 2,200,000 oil bottles, 55,000,000 charges, and 5,000 barrels.[5] Rifles were repaired, to the

[1] D.D.G.E./E.M. 3/949.

[2] HIST. REC./H/1122.1/4.

[3] 6,000 Mark IX Lewis ; 11,539 Maxim (including conversions) ; 112,787 Vickers.

[4] They included, for instance, apparatus for firing miniature ammunition, water bags, feed blocks, brushes, extractors, crank handles, hyposcopes, filling belt machines, muzzle attachment for ball firing, firing pins, plugs of different kinds, muzzle protectors, cleaning rods, connecting rods, shoulder pieces, fore and tangent sights, muzzle attachment cleaners, triggers, steam tubes, tumblers, water vessels.

[5] The various rifle parts and accessories produced were butt plates, screw plates, clearing plugs, back and fore sight protectors, cleaning rods, rifle attach ments for trench howitzers, actions of artillery carbines, aim correctors, stock butt anvils, bits, fore sight blades, bodies, breech and locking bolts, wire breakers, tube aiming cleaners, cocking pieces, pull through cords, fore-end floats, gauges, sword bayonet grips, breech bolt heads, armourers' horses, action implements, lances, backsight leaves, linings, lockets, magazine cases, magazines, mandrils.

number of about 1,400,000, and repairs were also effected to cavalry swords, scabbards, bayonets, pistols and lances.[1]

The cost of rifle production varied but little. In June 1916 the cost per rifle was estimated at £3 5s.[2] and in June 1918, including depreciation and overhead charges, was £3 18s. 5d.[3]

The factory was fortunate in suffering but little damage from fire and air attacks. At no time was there any loss of output from fire, and although in the autumn of 1917 a serious fire broke out, the damage was confined to the women's welfare quarters.[4]

A number of air raids occurred in the district, but again no structural damage was done. The screening of the lights was a matter of considerable difficulty, and a special inspection by airship proved that the factory could be easily located. In the darkened paths and roads outside accidents not infrequently occurred, especially in the water ways.[5]

The effect of raids on output was, in comparison with the number of attacks, small. For instance, of eleven raids in the latter part of 1917 involving a total loss of about eighteen hours, nine had no effect on output, but as a result of the remaining two, a total of 2,600 rifles and a corresponding number of components were lost.[6]

In spite of the special difficulties of manufacture at Enfield the factory proved its capacity for effective development and to the soundness of its organisation the peddled scheme owed practically all its success. It had the inestimable advantage of a highly trained nucleus staff, and the quality of the work was particularly high. The resulting product was a thoroughly sound and highly finished weapon which fulfilled its object by retaining the absolute confidence of the soldier on the field.

IV. The Royal Gunpowder Factory, Waltham Abbey.[7]

The Royal Gunpowder Factory, Waltham Abbey, is of very great antiquity, the earliest known record of Waltham Abbey Powder Mills dating back to the reign of Elizabeth. In 1787, the factory was purchased by the Government, and since then it has always been known as the Royal Gunpowder Factory. In 1872, the production of guncotton on a manufacturing scale was commenced, and in 1885, 100 acres of land, known as Quinton Hill, were purchased and a new guncotton factory erected which started work in 1890. In 1891, the production of cordite commenced, the necessary nitroglycerine factory and buildings for making cordite having been erected on Quinton Hill after the recommendation made in 1890 that the smokeless powder known as

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[1] The total numbers of these arms repaired were 1,535,034.
[2] 94/R/392. Material 11s. 8d.; Wages, £2 2s. 8d. Indirect expenses 10s. 8d.
[3] D.D.G.E./E.M. 3/1083.
[4] D.D.G.E./E.M. 4/221, 280.
[5] O.F./Bldgs./023.
[6] D.D.G.E./E.M. 4/237.
[7] HIST. REC./H/1122.12/1, 2; HIST. REC./R/1122.12/2; 1122.1/9; 1122.7/24, 26; 95/C/314.

cordite should be used for the British service. In 1901, the introduction of cordite M.D. necessitated considerable extensions. The manufacture of tetryl was begun in 1910 on a very small scale.

At the outbreak of the war, Waltham Abbey was the only government factory making cordite, gunpowder, guncotton and tetryl. It was controlled on behalf of both services by the War Department through the administration of the Superintendent of Waltham Abbey and Enfield. In August, 1915, it was taken over by the Ministry of Munitions, and was administered by the Director General of Munitions Supply until transferred in January, 1916, to the Director General of Explosives Supply. It was, thereafter, directly controlled by the Propellants Branch of the Explosives Supply Department and was under the management of a Superintendent. For some time after its transfer to the Ministry of Munitions a part of its output was still allocated to the Admiralty, but in October, 1916, the Admiralty, having accumulated large stocks of cordite, agreed to the transfer of the whole of the Royal Gunpowder Factory cordite output to the Ministry.

The nature of the site, which consisted of a long strip of land, limited the expansion of the factory, and prevented the lay-out of new plant from being arranged along the simplest and most economical lines.

As regards cordite, the approximate maximum pre-war capacity of the factory was 70 tons a week. By August, 1915, its output had been increased to 140 tons of cordite M.D. per week. After its transfer to the Ministry of Munitions the capacity of the factory was further increased to 250 tons of cordite R.D.B., or 200 tons of cordite M.D. per week. The manufacture of R.D.B. flake cordite was introduced towards the close of 1917.

The actual output of gunpowder in the four months preceding the outbreak of the war averaged $4\frac{1}{2}$ tons a week. In the next four months this average rose to $8\frac{1}{2}$ tons. The plant then existing proved adequate to meet the demands made on it.

Prior to the war tetryl was made on little more than a laboratory scale. Plant extensions were, however, made in the early days of the war, and in September, 1915, the output was rather over 5,000 lbs. per week. By January, 1916, increased plant to reach an output of 25,000 lbs. per week had been installed. Fires unfortunately destroyed two drying stoves in July, 1916, the new acetone purification house on 22 February, 1917, and the purification and corning house on 15 February, 1918.

During 1917, the water purification process for producing Grade II tetryl was placed on a satisfactory basis and in 1918 a temporary plant was installed for the production of Grade IA tetryl by the nitric acid purification process and a permanent plant capable of dealing with 20,000 lbs. per week was nearing completion when the Armistice was signed.

The total factory output during the whole period of the war was 31,716 tons of cordite, 1,629 tons of gunpowder, 10 tons of gunpowder pellets, 1,632 tons of tetryl, 2,424 tons of guncotton and 252 tons of fuse powder.

At the outbreak of the war 918 male workers were employed. By March, 1916, the number had risen to 3,800. In April, 1916, dilution with female labour was begun and by May, 1917, the employees numbered 2,637 men, 478 boys, 1,832 women, and 314 girls, *i.e.* a total of 5,261. The maximum number employed was in March, 1918, the figures then being 2,691 men, 431 boys, 2,277 women, and 331 girls, giving a total of 5,730. The original employees were practically all local residents. It proved possible to draw a sufficiency of labour, both male and female, from the surrounding districts and the North of London. On the signing of the Armistice steps were taken to reduce output, to discharge all the women workers, and to reduce the number of men and boys to approximately pre-war number.

V. The Royal Aircraft Establishment, Farnborough.

The Royal Aircraft Factory, known since 1918 as the Royal Aircraft Establishment, was founded as a balloon factory in 1905. In 1911 it became the Army Aircraft Factory, and in 1912 the Royal Aircraft Factory.[1] Until the end of 1913 airships and aeroplanes were designed and built there. All airships were transferred to the navy at the end of 1913, and the Royal Aircraft Factory was from that time devoted to research and invention in heavier than air craft. The Royal Aircraft Factory nominally existed as a technical department for both services, but the Admiralty made comparatively little use of its resources and developed an independent technical branch. Thus, on the outbreak of war, the establishment at Farnborough was entirely under the control of the Director-General of Military Aeronautics.

For the first two years of the war much pioneer work in design both of aeroplanes and aero-engines was carried out at the factory. A certain amount of manufacture was also done in connection with experimental machines and in emergency cases to supplement the failures of contractors. Engine repairs and the provision of spares, both for engines and aeroplanes, were important branches of the work, and between March, 1915, and November, 1918, 2,310 engines were repaired. A great deal of research was done on materials used in manufacture, especially fabric and dope, for the investigation of which a chemical laboratory existed. One of the particular features of the factory was the full-scale experimental and research work carried out there. It was found towards the end of 1915 that the amount of design work carried on at the factory tended to prevent healthy competition by private firms, and was the cause of jealousy on the part of contractors, and from this time it was found desirable to reduce the original design work done at Farnborough and to give further encouragement to the designs of private firms.

The factory was administered under the Director of Military Aeronautics by a superintendent. An enquiry was held in May, 1916,

[1] *Final Report of Committee on Administration and Command of Royal Flying Corps.*

on the organisation of the factory, and it was suggested by the committee that a Board of Management should be formed consisting of a Chairman or Director, a Superintendent of Designs and a Superintendent of Manufacture, who should be preferably civilians, with a Military Adviser without distinctive executive duties. The Air Board did not agree with this recommendation, believing that a Board of Management would not be well adapted to the exigencies of a military organisation. They recommended a single superintendent with two subordinate officers who should be heads of the design and production branches respectively.

The suggestion of the Committee that the capacity of the factory should be directed to an increase of the current manufacture of aeroplanes and engines raised a difficult question. From a financial point of view such an extension was desirable, as the costs of an experimental establishment such as Farnborough were bound to be high. On the other hand, the limited amount of production already carried out at the factory had aroused jealousy on the part of private manufacturers, and the Air Board recommended the development of the experimental side of the work, rather than the production side.

A reconstruction of the management of the factory, on the lines recommended by the Air Board, took place in September, 1916, when Mr., afterwards Sir Henry, Fowler, became Superintendent.

The position of the factory under the new conditions, which resulted from the transference of supply to the Ministry of Munitions in March, 1917, was the subject of much debate.[1] The experimental side of the establishment seemed to be the province of the technical department of the Air Board, while the manufacturing side clearly belonged to the supply department. It was finally arranged to place the factory under the supply department, its Superintendent being responsible to the Controller of Aeronautical Supplies. It was treated like any other contractor and could submit designs for the approval of the technical department. It was still used mainly as an experimental factory, and its work was not greatly modified under the new conditions.[2] Its design branch provided the supply department with the knowledge necessary for the production of such highly technical stores as aircraft and aero-engines, but its facilities were available for any experiments desired by the technical department.[3] By the middle of 1917, the factory was re-organised. At the beginning of 1918, Mr. Sydney Smith was appointed as Superintendent in succession to Sir Henry Fowler, who had been transferred to the Air Board as Assistant Director-General of Aircraft Production. About the same time the technical department was transferred to the Department of Aircraft Production, thus bringing the Royal Aircraft Factory under the sole control of the Ministry of Munitions. The establishment was handed over to the Air Ministry on 1st January, 1920.

In its general outlines, the organisation of Farnborough resembled that of Woolwich Arsenal. On the outbreak of war, the staff of trained

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[1] A.C. 137.
[2] Hist. Rec./R/1960/1.
[3] C.R. 4402.

engineers at Farnborough served both as a supply for the required supervising and inspecting staff and also as a nucleus for training new men for the work, while the manufacturing capacity at Farnborough served to carry on production over the period while the industry was being built up. For the first few months of the war final inspection and flight test of all machines were carried out at Farnborough, but this led to delay and congestion as output increased. At the beginning of 1915 this work had to be decentralised and aerodromes and inspecting staff were provided at other centres throughout the country. On the outbreak of war a large proportion of the spares supply for the Royal Flying Corps was still being dealt with by the factory both as regards provision and storage. The Aeronautical Ordnance Department had, however, already been established at Pinehurst, and in August, 1914, it took over from the factory the Royal Flying Corps stores work, with the exception of certain special items such as instruments.

The system of issue of drawings differed at Farnborough and Woolwich. At Woolwich the Inspection Department issued all drawings to contractors, but at Farnborough, owing to the fact that for the first year of the war the majority of machines built by contractors were of factory design, drawings were issued by the Superintendent of the Royal Aircraft Factory direct to contractors. The fact that frequent alterations in drawings were necessary after their issue gave ground for criticism of the factory, and from the beginning of 1916 every effort was made to reduce the amount of direct communication between the factory and contractors. The establishment of a technical branch at headquarters early in 1916 relieved the factory of all duties in connection with the issue of drawings and specifications.

It was possible to carry out dilution of labour to a large extent at Farnborough: female labour had always been used in the dope and fabric shops, and during the war dilution took place in the other manufacturing departments, and also, where possible, in the technical and administrative departments.

The strength of the Royal Aircraft Factory on 26th March, 1916, was 4,222 and the wages bill (excluding the salaries of eight chief officials) for the week ending 26th March, 1916, totalled £10,409.

The costing system at the factory in the early days was comparatively simple, but a very elaborate system was introduced by the Ministry of Munitions. After the factory came under the Air Ministry the system was completely revised and simplified. Very detailed records of the materials used in the manufacture of each part of an aeroplane, and of the course through which the components passed in the various stages from the raw material to the finished article, were introduced in the early days of the factory to ensure that every detail of an experimental machine might be traced back to the particular batch of material from which it was made.

The following tables show the output of aeroplanes from the factory during the last four years of the war, and the number of engines repaired during the same period.

TABLE IV.

Issues from the Royal Aircraft Establishment, Farnborough.

(*a*) AEROPLANES MANUFACTURED, JANUARY, 1915, TO NOVEMBER, 1918.

Type.	1915.	1916.	1917.	1918.	Total.
R.E. 5	2	—	—	—	2
R.E. 8	—	39	6	—	45
F.E. 2A	12	—	—	—	12
F.E. 2B	11	36	—	—	47
F.E. 2C	—	2	—	—	2
F.E. 2D	—	74	11	—	85
F.E. 4	—	2	—	—	2
F.E. 8	2	—	—	—	2
F.E. 9	—	—	3	—	3
S.E. 4A	4	—	—	—	4
S.E. 5	—	2	132	—	134
S.E. 5A	—	—	—	102	102
N.E. 1	—	—	4	2	6
C.E. 1	—	—	1	1	2
A.E. 3	—	—	—	3	3
Handley Page	—	—	—	24	24
Vickers Bomber	—	—	—	1	1
Special	—	—	6	—	6
Totals	31	155	163	133	482

(*b*) ENGINES REPAIRED FOR ROYAL AIR FORCE, MARCH, 1915, TO NOVEMBER, 1918.

Type.	1915.	1916.	1917.	1918.	Total.
Renault 60 h.p.	1	—	—	—	1
,, 70 h.p.	87	41	—	—	128
,, 75 h.p.	—	6	—	—	6
,, 80 h.p.	—	3	—	—	3
Gnome 80 h.p.	112	83	—	—	195
Mono 100 h.p.	13	6	—	—	19
Le Rhone 100 h.p.	1	—	—	—	1
Clerget 80 h.p.	—	3	—	—	3
Green 100 h.p.	—	1	—	—	1
Beardmore	—	60	—	—	60
Rolls Royce	—	51	60	—	111
Sunbeam	—	—	6	—	6
Hispano	—	—	22	937	959
R.A.F. 1A	25	276	243	—	544
R.A.F. 3A	—	—	2	—	2
R.A.F. 4	—	—	174	—	174
R.A.F. 4A	—	29	89	12	130
R.A.F. 5	—	—	1	—	1
Totals	239	559	597	949	2,344

CHAPTER II.

HIS MAJESTY'S EXPLOSIVES FACTORIES.[1]

I.—Introduction.

(a) *Development of the National Factories for Explosives Production.*

The first factories erected for explosives manufacture were the earliest of the numerous state factories which were established for the purposes of the war. In October, 1914, there arose an unprecedentedly large demand for T.N.T. The manufacture of high explosives had never been undertaken by the Ordnance Factories. There was practically no trade capacity for manufacture of military T.N.T., and the stocks of the commercial explosive which were available needed treatment to bring them up to service standards. As soon as power to requisition the entire output of factories had been taken under the Defence of the Realm (Consolidation) Act, in November, 1914, arrangements were made by the War Department to acquire and operate works at Rainham which were suitable for purifying the commercial product. The manufacture of T.N.T. presented grave technical difficulties and the demand for it was in practice limited only by the amount of the raw material, toluol, which was available. Economical methods of manufacture were accordingly essential and the Committee on High Explosives, under the presidency of Lord Moulton, favoured the erection of a national factory for the purpose, in order to ensure control over the layout, to facilitate development in accordance with the information as to manufacturing processes which was daily increasing and to make the best use of the limited number of technical experts who had special knowledge of this subject. Mr. K. B. Quinan was summoned from South Africa, towards the end of December, 1914, to construct the first national T.N.T. factory at Oldbury, and the work of erection began in the following month. The factory was to be operated under an agency agreement by a well-known firm of acid-makers, Messrs. Chance and Hunt, and an essential part of the project was the transfer from Rotterdam to Portishead of the Asiatic Petroleum Company's plant for distilling toluol from Borneo Petroleum. The Asiatic Petroleum Company undertook to operate this distillery for the State under an agency agreement and also to erect at Oldbury plant for nitrating the toluol up to M.N.T., the basic material for the national T.N.T. factory, of which the M.N.T. plant subsequently became an integral part.

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[1] See Vol. X, Part IV, for the authorities for this account, and for the relations of the national factories to the general arrangements for explosive supply.

Meantime, naval authorities had decided in favour of the erection of a Royal Naval Cordite Factory as preferable to the advance of large sums for the extension of plant by the chief explosive makers, who were unwilling that subsidised plant should revert to the State at the end of the war. The scheme for this factory, which was ultimately erected at Holton Heath, near Poole, was authorised by the First Lord of the Admiralty early in February, 1915. It was not, however, considered that the guncotton section could be in operation at a sufficiently early date, and Lord Moulton undertook to expedite guncotton manufacture by converting derelict works at Queen's Ferry into a government factory for this purpose. The project was first mooted at the end of February, but the site was not available until the middle of May, and at the end of that month the output anticipated from the factory was earmarked for military use.

From May, 1915, till the end of that year, the state factories for explosive manufacture developed with great rapidity. It was not considered necessary in May, 1915, to make further extensions to the capacity for making high explosives in order to balance the schemes of the Munitions of War Committee for increased shell production; but a project for manufacturing 2,000 tons of some substitute propulsive monthly was set on foot by that committee. Lord Moulton undertook to ensure this supply by erecting a single large, national factory. Preparations for the new factory were continued throughout the month of June, and, on 26 June, shortly after his appointment as Minister of Munitions, Mr. Lloyd George gave Lord Moulton formal authority to proceed with its erection. Thus originated the enormous state factory at Gretna for the manufacture of cordite R.D.B., with the entirely new township created in the open country for the housing of the operatives.

The extended gun ammunition programmes formulated in the summer of 1915 gave rise to large extensions to the national plant for explosive manufacture. The capacity of Gretna was increased. The Oldbury and Portishead factories for T.N.T., M.N.T. and toluol were duplicated at Queen's Ferry, Sandycroft and Barrow. Contractors' works for making T.N.T. at Penrhyn Deudraeth, which had been destroyed by explosion, were re-erected as a government factory. Land was taken at Watford for a national ammonal factory to supplement the trade capacity for this explosive, which had already been extended to the utmost to provide against the increasing output of trench mortar bombs.

Throughout the year, the practice continued of erecting new national plant for making explosives or their materials. A serious shortage of tetryl in the autumn was met by extending the plant at the Royal Gunpowder factory and also by adding a tetryl section to the Queen's Ferry factory. Manufacture of synthetic phenol was undertaken in a state factory erected at Ellesmere Port in October, 1915, and erection of a government refinery for commercial toluol was begun at Trafford Park in that same month. Ammonium perchlorate production was arranged at a national factory at Langwith

in the following November. Grillo plant for oleum manufacture was added to the Queen's Ferry factory in December, 1915.

In addition to establishing new works, the Explosives Supply Department of the Ministry of Munitions also took over certain contractors' works for various reasons. The complexity of the negotiations with Nobel's Explosives Company for erecting plant at Pembrey to manufacture T.N.T., cordite and ballistite on behalf of the Navy as well as the Army led to an agreement in October, 1915, for the amalgamation of the contracts relating to this factory and for its operation by the firm as an agency factory under the Ministry as from January, 1917, onwards. To improve output, two T.N.T. factories at Hackney Wick and Litherland and a plenol factory at Sutton Oak were nationalised in July, 1915, March and May, 1916, respectively. A gun cotton factory, leased from the Belgian Government by the Colnbrook Chemicals and Explosives Company Limited was nationalised in June, 1916, on account of the unsatisfactory position of its output and finances.

In April, 1916, land was taken at Craigleith, outside Edinburgh, for the erection of a new national T.N.T. factory. It was to supersede works which had been successfully operated by members of the Edinburgh University and others trading as the Lothian Chemical Company, but was dangerously situated in a congested neighbourhood. No further factories were erected for T.N.T. production, but by the summer of 1916 all trade capacity for picric acid manufacture had been exhausted and a project for the national manufacture of this explosive was set on foot, chiefly with a view to utilising surplus quantities of phenol. A site for a large picric acid factory was found at Avonmouth, and the scheme included the erection of a large oleum plant in connection with neighbouring plant for roasting zinc ore. Later in the year three new state factories were projected for picric acid manufacture. These were situated at Bradley, Greetland and Lytham, and were operated by agents, whereas the Avonmouth factory was under the direct control of the Department.

At the end of 1916 plans were also made to construct at Henbury and Irvine two national factories to produce at home nitrocellulose powder, an American explosive which had previously been obtained from overseas only. This project was based upon existing uncertainty as to the maintenance of supplies from the United States. With the entry of the American Government into the war, and the increased stringency in the shipping position, the scheme was greatly reduced. The project for the Henbury factory was eventually abandoned in May, 1917. The construction of the factory at Irvine was continued slowly. For similar reasons the picric acid plant at Avonmouth was restricted to two-thirds of the original scheme, and owing to the gradual abandonment of picric acid, the plant was never used for this purpose.

The growing stringency of the tonnage position led to the development of the home manufacture of ammonium nitrate, mainly by contractors working under cost plus percentage agreements, but also at a national factory which was erected at Swindon early in 1917.

State manufacture of calcium nitrate had been undertaken during 1916 at H.M. Factory, Victoria, which was at first operated by Messrs. Brunner, Mond in conjunction with trade factories for ammonium nitrate production in the Northwich district. A plan to erect a second national factory for calcium chloride on land adjacent to the Victoria Works was authorised in October, 1916, and abandoned towards the end of December, when the development of a simpler process had facilitated the erection of the self-contained ammonium nitrate factory at Swindon.

The erection of national plant for producing the complete explosive was brought to an end with the abandonment of the picric acid and nitrocellulose powder factories at Avonmouth and Henbury. Some new projects were, however, set on foot for the State manufacture of materials with a view to increasing home production. Several additions were planned in 1917 to the wood distillation factories which had already been established under Government control for the manufacture of acetone and other products. The cotton waste mills originally managed by the British and Foreign Supply Association were nationalised in August, 1917, with a view to a closer technical control over their operations. The very grave position in regard to shipments of sodium nitrate during the last two years of the war led to a project for an extensive national factory at Billingham for deriving nitrogen products from the atmosphere. The scheme passed through many vicissitudes. Erection of enormous national plants was no longer so simple a matter as in 1915. The original project of August, 1917, passed under the consideration of one committee of inquiry after another. The progress of the factory was seriously hampered by low priority, lack of labour and material, and in November, 1918, construction by the State was abandoned.[1]

(b) *Methods of Construction.*

The erection of enormous explosives factories for new or comparatively unknown operations presented very peculiar technical difficulties. Moreover, the number of chemical engineers with experience in this class of work was strictly limited. Indeed, it was very largely in order to make the best use of the expert knowledge available that the early decision was taken in favour of constructing national plant. The lay-out and erection of the factories at Oldbury and Queen's Ferry were the work of Mr. K. B. Quinan, who was also responsible for planning the Gretna factory. At Oldbury the agency firm undertook to provide labour and materials for the building operations. The construction of Queen's Ferry was more directly controlled from headquarters. For Gretna Messrs. Pearson and Sons were appointed construction managers with a large degree of autonomy. They were responsible also for the building of the townships, which were planned by the chief town-planning expert of the Local Government Board, Mr. Raymond Unwin. The purchase and inspection of plant and material

[1] 74./H.E.N./136.

for Queen's Ferry and Gretna was controlled by a member of the firm of Sir J. Wolfe-Barry. The provision of the huge water-supply needed by the new factories rested with a special adviser, Mr. Hawksley, appointed in July, 1915. The Contracts Section of the Explosives Supply Department was responsible for building and other agreements. By June, 1916, the pressure of construction work was becoming relaxed. Mr. Quinan's headquarter staff became the Factories Branch, controlling both the construction and administration of the national factories with the exception of Oldbury, Rainham and Gadbrook, which were administered by the Contracts Section, and of the wood distillation and cotton waste factories, which, together with the Royal Gunpowder Factory, were controlled by the Propellants Branch.

At the same time special experts were employed so far as was possible in connection with the building of particular factories. Thus a consultant engineer with particular knowledge of ammonal plant was appointed at Watford, and an agreement was also made for advice and assistance from the ammonal monopolists (Roburite and Ammonal Ltd.). Nobel's Explosives Company, Ltd., had completed the construction of Pembrey before it was nationalised. They, also, became responsible for the lay-out and erection of Irvine, for which they had special facilities. The three agency firms who undertook to construct picric acid factories in December, 1916, had already successfully established trade factories for the same explosive. At Langwith the process adopted for ammonium perchlorate needed special power plant and, in addition to a construction manager, special consultants on power gas were appointed.

The technical difficulties of construction were greatly enhanced by the novelty of the processes for which the factories were planned, while, in order to expedite construction, the details of the lay-out were often settled as building proceeded. The M.N.T. and T.N.T. plants at Oldbury were installed in a few months. The larger Gretna factory took a year in the building. The construction programme at Queen's Ferry was changed from time to time. The site was occupied in May, 1915, and guncotton was first produced in the following December. In this, and numerous other factories, the sections were divided into distinct units so that actual operation did not await the completion of the factory. With growing difficulties in obtaining labour and plant, the constructional work became more and more delayed. It has been seen, for instance, that the erection of the factory at Billingham was eventually abandoned as a war measure on this account.

Nearly all National Explosives Factories were built on a time-and-line basis, since the concurrent development of process made repetition work, except for the comparatively small proportion of brick-work, quite impracticable. The disadvantages of this method were, however, experienced to the full. At Avonmouth, for example, a fifty per cent. reduction in the number of construction labourers made no perceptible decrease in results, while the quality of the work was often far finer than was necessary. The explosive factories were

particularly costly, owing mainly to the exceptional character of their plant and the experimental nature of much of the work which was undertaken. As a class they were also exceptionally numerous. They included some 33 factories and were equalled in number only by the National Shell Factories. Moreover, several of them, such as Gretna, Queen's Ferry and Oldbury were on a scale enormously greater than any single trade factory, and such factories as Queen's Ferry and Pembrey were in fact a group of establishments undertaking several absolutely distinct classes of work. By March, 1919 the total cost of the entire class, including factories for explosives materials but excluding expenditure on schemes which were entirely abortive, had reached nearly £25,000,000.[1] The two abandoned projects at Henbury and Billingham accounted for another £876,900, allowing for Henbury £154,400, the sum to which special liquidation committees had by then reduced the commitments and actual expenditure, which originally amounted to £3,585,000.

(c) *Achievements of the National Explosives Factories.*

The need for so large an outlay on new state factories was partly due to the entire lack of industrial capacity for certain explosives, such as T.N.T., or for their materials, such as acetone. Even where the industry was well-established, *e.g.*, in cordite manufacture, the necessary rate of output could only be obtained by constructing new factories, for which no post-war use seemed to exist. Accordingly explosives contractors were unwilling to extend their works beyond a certain point. It was largely by means of the national factories, that the explosive programme was invariably met. At the outbreak of war, state production was restricted to the Royal Gunpowder Factory, which made about 75 (short) tons of cordite and gunpowder weekly. In remarkable contrast was the average weekly output of over 2,000 tons of all classes of explosive produced by the national factories during the year 1917, when state manufacture had been organised to the full. The most remarkable item in this figure was the average output of over 1,000 tons of T.N.T. from the national factories as compared with 520 tons, the average weekly figure from all other sources. Since nearly 50 per cent. of the propellant supplies was purchased from overseas and the manufacture of ammonium nitrate was chiefly in the hands of the trade, the general proportion of all explosives made in national factories to those obtained from other sources was considerably less than in the case of T.N.T. Nevertheless, the output of explosives from state factories during the year 1917 was little less than one-third of the whole supplies, while during the year 1918 it rose to rather more than a third of the whole.[2]

In all, the new national explosives factories, which were set up during the war, produced 236,251 (short) tons of high explosive and 81,341 (short) tons of propulsive explosive, in addition to large

[1] The figure to the nearest hundred pounds was £24,873,400.

[2] These figures are based on the *Review of Munitions Output*, 1914-18, pp. 82-85.

quantities of explosive materials. The main details of their output is shown in the table which follows.

Output of H.M. Explosives Factories.[1]

	1914	1915	1916	1917	1918	Total
High Explosive:						
Picric Acid	—	—	—	1,376	3,265	4,641
T.N.T.	—	3,675[2]	20,795	52,723	53,746	130,939
Ammonium Nitrate ..	—	—	—	19,194	81,477	100,671
Total High Explosive	—	3,675	20,795	73,293	138,488	236,251
Propellant:—						
Cordite	—	—	2,350	39,473	35,454	77,277
Ballistite	—	—	—	781	—	781
N.C.T.	—	—	—	—	3,283	3,283
Total Propellant ..	—	—	2,350	40,254	38,737	81,341

While the enormous output of these factories was of vital importance, they also served other essential purposes. Many of them, particularly those for T.N.T., provided a means of working out absolutely new processes on a large scale. The manufacture of T.N.T. in state factories also enabled the Department to consider questions of safety side by side with considerations of output, and so to avoid the rigidity of the safety conditions applied to trade factories which undertook dangerous processes. It was for this purpose alone, for instance, that the T.N.T. purification factory at Gadbrook was accounted a government establishment. The factories also served a very special purpose in reducing the usage of raw materials and in fostering every kind of efficiency. An intricate system of cost and efficiency returns was established in them for this purpose. This system gave rise to a general competition in economy not only between individual national factories, but also, in several instances, between the national factories and trade manufacturers. The technical and practical efficiency of the factories reduced very considerably the cost of making explosives, particularly those classes of explosive of which little experience existed. The great size of many of the factories also tended to cheapness of production. Hence, they provided a very economical source of supply as compared with the alternative of purchase from America or even from British contractors. The relatively low cost of production in the national factories was a direct cause of very considerable reductions in the contract prices for high explosives during the year 1917.

In the year 1918, a considerable part of the plant which had been installed for picric acid manufacture was closed down by reason of the decreased use of that explosive. The factories chiefly affected were

[1] Figures denote short tons.

[2] An approximate figure only.

those erected for the production of phenol. It was, however, found possible to convert a large proportion of this plant for the manufacture of poison gas.

(d) *Staff and Operatives.*[1]

One of the main problems in establishing the explosives factories was the provision of adequate numbers of trained works chemists and process-workers. The number of trained technical men, and more particularly of chemical engineers, was strictly limited. The technical staffs of commercial firms were already sorely over-taxed. It was necessary to fall back upon the young and usually inexperienced chemists of the country, who were mostly without either works experience or administrative knowledge. These were selected and trained as works chemists on existing plant as the various factories started work. Towards the end of 1915, it also became necessary to organise a system of training for chemist foremen, since experience showed that the normal method of advancing operatives as foremen after a lengthy period of instruction would be impracticable in the time available and under the comparatively inexperienced works chemists from whom the factory staffs were being drawn. The new class of chemical foremen was created from intelligent young chemists who were drawn first from Great Britain, and subsequently from the Colonies or the Special Brigade, and were trained in the actual working of the process before they were put in charge of a shift.

Apart from the difficulties experienced in providing technical staff, the provision of labour for the National Explosives Factories was easy as compared with the National Shell and Projectile Factories. Operatives in the explosives industry were normally unskilled men, who obtained their experience from working in the factories themselves. This practice was continued in the national explosives factories. Over 30,500 operatives were employed in them during the autumn of 1918. The chief change made was in the employment of women, who then formed about 51 per cent. of the whole number of employees.

II. Individual Explosives Factories.

H.M. Factory, Avonmouth.[2]

Early in the summer of 1916, when the services were demanding very large supplies of picric acid, it was decided to erect a single national factory to produce 350 tons weekly, the largest quantity it was then thought possible to obtain from the benzol available for British use. In August, 1916, a site at Avonmouth, near Bristol, was selected for the erection of sulphuric acid plant, to be fed from the zinc concentrates obtained from the National Spelter Company, who were simultaneously building a factory on an adjacent site for

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[1] HIST. REC./R/1122.7/17.

[2] HIST. REC./H/1500/6, 1122.7/8; C.R./Filling/297; X.235/35; Southern 8/5315; 74/Avonmouth/1, 3, 94, 140.

roasting zinc ore. Early in the autumn the two schemes for picric and sulphuric acid production were combined, and by October, 1916, plans were completed for the establishment of a factory at Avonmouth next to the Spelter Company's works to contain both the sulphuric and picric acid plant.

The site covered nearly 249 acres on the banks of the Severn, $1\frac{1}{4}$ miles north of the Great Western Station at Avonmouth, and 1 mile from Avonmouth Docks. The land was private property and possession was taken under the Defence of the Realm Act, an annual rent of £472 being paid from September, 1916, in addition to compensation to the tenants. Sidings connected the factory with the Great Western Railway main line and railway transport was always satisfactory, while considerable traffic could reach the factory from the docks. The factory was directly controlled by the Factories Branch of the Explosives Supply Department and construction was begun by November, 1916. In March, 1917, the proposed picric plant was cut down by a third, and though much of the remaining plant was constructed by the end of 1917, its use for the production of picric acid was then abandoned before any output had been obtained. These changes were the result of the growing stringency in tonnage and the consequent abandonment of picric acid. Some of the picric acid plant was subsequently converted for mustard gas (H.S.) manufacture.

The plant for oleum (fuming sulphuric acid) had been planned on a larger basis than was needed for the picric acid plant in order to provide additional acid for the explosives and fertiliser programme. Ten grillo units were erected and of these one unit began work on 3 January, 1918, the first output of oleum being sent to H.M. Factory, Pembrey. Production from this one unit continued till August, 1918, when in view of the decreased demand for sulphuric acid, it was necessary to close down the grillo plant.

Early in June, 1918, it was decided that the bulk of the H.S. gas required should be made at Avonmouth and delivered to Chittening, $1\frac{1}{2}$ miles away, for charging into shell. The factory was therefore laid out for the production of 500 tons weekly, the full output to be reached in December, 1918, but many difficulties developed and the greatest weekly output reached before the Armistice was 125 tons. When production began on 3 July, 1918, the factory was at first hampered by transport troubles and a month elapsed before an efficient system of tank wagons was evolved, in which the H.S. was conveyed to Chittening, where members of the Avonmouth staff transferred it to the charging-factory's drums. In the autumn, plans were made for laying down pipe lines from Avonmouth to Chittening, but these were not completed before the Armistice. The total amount of H.S. produced by 26 July, 1918, was 32 tons ; but by the first week of August the output reached 10 tons daily and there was a prospect of speedy increase. On 21 August, however, it was necessary to cease manufacture in order to repair and clean the plant, as owing to an accident to the ethylene plant, the vessels and tanks had become impregnated with sulphur. Production began again on 4 September, 1918, at 5 tons daily, and it was hoped very quickly to attain a good output. On 23 October, however,

the factory was again closed, since practically all of the technical staff were incapacitated, partly owing to climatic conditions which intensified the difficulty of ventilation. The quality of the H.S. produced varied from time to time, and the Chittening factory had considerable difficulty in handling the product from Avonmouth. The chief obstacle to increased output was sulphur deposition, and just before the Armistice certain alterations were carried out which dealt with this problem.

Much difficulty was experienced in obtaining skilled labour both for construction and production, and about 50 per cent. of the skilled workers employed were imported through various enrolment schemes. As this additional labour could not be accommodated in Avonmouth 99 per cent. had to live at Bristol. A very efficient train service was provided for these and the Ministry also set on foot a housing scheme to provide workmen's cottages at Shirehampton, a village two miles from the factory. Owing to the experimental nature of the lay-out, the work of construction was carried out on the "time-and-line" basis, which did not prove the most economical form of contract, the number of workmen employed being at one time reduced from 4,300 to 2,000 without any appreciable decrease in the work accomplished, while the quality of the work was much finer than was required for such a factory. Women were employed as construction labourers on the grillo unit, and later on the ethylene plant for H.S. production and their output on both processes compared favourably with that of male labour. Construction was hampered on several occasions by labour disputes as to the rate of wages, while later the question of women's wages became the subject of much dispute and was submitted to arbitration. When the factory was producing H.S. the very high proportion of labour casualties, amounting at one time to 70 per cent. of the labour employed, spread a feeling of considerable alarm in the neighbourhood, and greatly increased the difficulty of obtaining workers for the factory. Owing to the nature of the work on H.S. frequent periods of rest or work away from the gas were necessary. The number of workers employed at the factory in October 1918 was 224, of whom 39·3 per cent. were women.

The cost of the factory for picric and sulphuric acid production was estimated at the end of 1917 as £1,400,000, but the actual figures differed widely from estimates owing to the changes in programme which followed. The grillo plant was shown to be the cheapest producer of SO_3 of any plant under the Ministry's control; but the picric plant, costing £300,000, was never put to its proper use, and only certain units were subsequently converted to poison gas manufacture. The actual expenditure to March, 1919, was £1,578,200.

H.M. Factory, Bradley.[1]

The national factory at Bradley, in Yorkshire, was one of the three factories planned in December, 1916, of which each was to produce 80 tons of picric acid weekly.[2] The factory was managed by Major L. B.

[1] 74/Lytham/14; HIST. REC./R/400/57, 1122/45; HIST. REC./H/1500/6; 74/Bradley/1, 51; X/Bradley/2/1.

[2] *See* below, under Lytham, p. 66.

Holliday, and the agreement for erection and management differed slightly from those signed by the firms at Lytham and Greetland in that, in this case, the fee for construction was £3,000, and the remuneration for management of $\frac{1}{10}$d. on each pound of picric acid produced was only calculated on picric which was up to government specification, though in the other two cases the pure picric contents in the waste picric produced were included. The firm also had the option to purchase the factory under certain conditions.

The site selected covered an area of rather more than 26 acres, near to Major Holliday's works at Deighton, but separated from them by a railway embankment high enough to prevent any danger to one factory from the other. It was bounded on the one side by the railway and on the other by a canal, and the factory was thus assured of good transport facilities by rail or barge. The land was the property of private owners and of the Midland Railway Company, and possession was taken under the Defence of the Realm Act.

Construction began in January 1917, while Major Holliday was carrying out experiments in his own works, with a view to developing an improved process for picric production. In February and March, work was almost suspended owing to the delays which occurred in laying the necessary sidings and the consequent non-arrival of plant. Arrangements were made with the Huddersfield Corporation for the disposal of the effluent, a matter of considerable difficulty. In November, 1917, an elaborate installation was begun for drawing an additional water supply from the River Calder. In February, 1918, when the demand for picric acid had diminished, arrangements were made for the completion of the factory and the carrying out of experimental runs to demonstrate the process; but for these the quantities dealt with were to be as small as possible and no regular production was to be undertaken. After 30 April, 1918, only the staff necessary to keep the plant from deterioration was employed.

As Major Holliday's experiments had proved satisfactory, the plant at Bradley was set up for a new process for converting synthetic phenol into picric acid, somewhat similar to that commonly adopted for manufacture from dinitrophenol. All the waste acid was to be reconcentrated, and, though during experimental work the cost was high, owing to the very strong acids used, it was thought that when the factory was in full working order the new method would give a better yield of picric at less cost than the old pot process. After some trials had been carried through, it was decided to cease production of picric in the firm's own works on 30 June, 1918, and begin in the new factory on 1 July, but, though deliveries stopped from the firm, the factory could not be started owing to the serious effects of the influenza epidemic.

In September, 1918, part of the plant was running with a production of about 10 tons weekly, but the work was still of a somewhat experimental nature, and a considerable amount of construction was still in progress. Some improvement was made in October, and by the end of the month despatches amounted to upwards of 30 tons, but after the Armistice only a small amount of drying and repacking was carried on.

The labour requirements of the factory were estimated in January, 1917, at 150 men and 70 women, and both men and women were employed in 1918. The total number of employees in October, 1918, was 370, of whom 21·1 per cent. were women.

The estimated capital expenditure was £360,000, the cost of the plant being reckoned as £110,000. Owing to the short time during which the factory was at work, it was impossible to make any actual tests of the comparative costs or efficiency of the plant. The capital expenditure to March, 1919, was £369,500.

H.M. Factory, Craigleith (Edinburgh).[1]

The national factory at Craigleith, which was established in 1916, was the last of those built for the production of T.N.T., and was operated as an agency factory by the Lothian Chemical Company. This company had been formed in the early summer of 1915 by a professor of chemistry of Edinburgh University, his assistant and a works manager, to erect plant in Edinburgh for the manufacture of T.N.T. They had proved most successful contractors, but they had been instructed to cease work in June, 1916, owing to the danger arising from the position of their explosives factory in the centre of a congested area in the city. At the same time, to utilise the excellent works practice and chemical skill of the staff, projects were considered for a new factory at Craigleith, some distance out of Edinburgh. As the company's available capital was limited, the Government decided to erect the new factory as a national establishment, to be managed by the company as agents.

The Craigleith site was taken over under the Defence of the Realm Act on 14 April, 1916, and the agreement for the management was signed on 20 June. By its terms the company undertook the entire design and lay-out of the factory and the supervision of its erection and equipment, receiving a lump sum remuneration. The Ministry was to pay all capital expenditure, and when production began was to be responsible for working costs, while the company received a management commission varying from 1*d.* to $\frac{3}{8}$*d.* on every pound of T.N.T., according as the cost of production ranged from £75 to £95 a ton. A subsequent revision of the agreement, made in view of changes in the T.N.T. specification, increased the erection fee to £2,650, and raised the sliding scale.

The works were laid out for a capacity of 35 tons weekly, and it was hoped to complete construction by the end of 1916. In December, however, it appeared that the plant was not well balanced, and it was decided that, while rectification of this matter was in process, the whole capacity should be raised to 50 tons weekly. Some trouble also occurred on the concentrators, and production was not actually started until February, 1917. The full rated output was reached by 10 November, 1917.

The process was very carefully controlled by the chemical staff, and the use of material was economical. The chief difficulty arose

[1] 74/L./61,164 ; 74/Craigleith/2, 6, 12, 82, 88, 95 ; C.R. 2913.

from the imperfect working of the concentrators, which permitted a considerable escape of noxious fumes. These gave rise to complaints from the city authorities, and rendered working conditions unsatisfactory. Some cases of toxic jaundice occurred among the women workers, and were attributed to dusty surroundings and bad handling, but steps were taken in August, 1918, to remedy these defects and improve the welfare conditions generally, and the proportion of sickness was not high compared with that in other works of a similar nature. The total number employed in the factory was, roughly, 300 in the spring of 1917, and had increased to 412 by October, 1918, when the proportion of female labour was 44·4 per cent. of the whole.

On 11 November, 1918, instructions were sent to the manager to cease manufacture as soon as possible, and it was estimated that actual production would stop at the end of the month.

The original estimate of capital expenditure on the factory was £40,940. Subsequent additions raised this figure, and the actual expenditure to March, 1919, was £67,900.

H.M. Factory, Ellesmere Port.[1]

This factory was built on five acres of land in Cheshire, originally rented from the Ship Canal Portland Cement Company. Later, in September, 1917, the freehold of the land was purchased. The site was chosen largely on account of its accessibility by means of the extension of an already existing railway siding, and also by means of the Manchester Ship Canal, beside which it lay. The proposal to erect a government factory for the production of 10 tons of synthetic phenol a day was made when, in October, 1915, it became clear that in order to provide for the picric acid programme it was necessary to increase the supplies of phenol. The standard method of manufacture was used, *i.e.*, synthesis from benzene through benzene sulphonic acid, and the process adopted had, in common with all others, the two stages of sulphonation and fusion. The details of neutralisation, etc., were, however, peculiar to the process, and preliminary experiments were carried out with experimental plant at University College before the design of plant and general lay-out was embarked on. The drying process adopted was protected by a patent, the rights of which were vested in Messrs. Brunner, Mond. They agreed, however, to allow the Government to use the process for the production of munitions of war. The construction of the factory was begun in March, 1916. It was completed in February, 1917. Some delay was caused both by scarcity of labour and by an extension of the original design. The area of the buildings erected was 410,601 square feet. From the first the factory was directly controlled by the Explosives Supply Department.

The original lay-out was for an output of 10 tons of phenol a day, but before the completion of the general lay-out it was realised that the housing accommodation of nearly every plant unit was sufficient to allow of an ultimate extension of plant to produce 15 tons a day.

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[1] Hist. Rec./H/1122.7/16.

It was therefore decided to make the buildings uniformly capable of housing the additional plant necessary for such an output. Production began in May, 1917, and the maximum output of 70 tons a week, for which the factory had been planned, was reached by March, 1918, when the factory was about to be closed by reason of the decreased demand for picric acid. The total output of phenol was 878 tons. In June, 1918, however, a proposal was on foot to use the factory for the manufacture of poison gas, and in July it was decided that Ellesmere Port should meet a demand for certain arsenic compounds. Some alterations and new plant were required. The estimated output of 40 tons a week was not at first realised; but the factory produced nearly 200 tons of arsenic compounds between August, 1918 and the date when it was finally closed down.

Owing to the urgency of the demand for poison gas, military labour was employed both for construction and subsequently for process work in connection with production. At the end of 1917, 386 workpeople were employed, 35·2 per cent. being women. In October, 1918, the total number was 249, and only 7·6 per cent. were women.

The capital expenditure down to 31 March, 1919, was £160,800, and was inclusive of the cost of converting plant for poison gas manufacture at an outlay of about £20,000.

H.M. Factory, Gadbrook.[1]

The factory for T.N.T. purification at Gadbrook was built on 59 acres of land in a sparsely populated district about two miles from Northwich. Part of the land was held by agreement with Messrs. Brunner, Mond at a rental of £3 per annum and the remainder was taken over under the Defence of the Realm Act at a rental of £2 per annum. The buildings, which were erected at the cost of the Government, covered an area of 95,135 square feet. The Ministry had an option to purchase the land within one month of the termination of the agreement, and if this option was not exercised the company might buy the works.

The factory was erected solely in order to meet the need for additional plant for T.N.T. purification by the early methods involving the use of alcohol, since in the spring of 1915 it was found that the Rainham factory could not treat the quantities required, and it was not considered desirable to erect purification works in the same place as manufacturing works on account of special danger risks consequent on the use of alcohol. In May, 1915, Messrs. Brunner, Mond were invited to carry out experiments with a view to devising a less costly and speedier process than those in use, and towards the end of the month experimental work was done by the firm at their Winnington works, information having first been obtained from Messrs. Nobel's, and the Clayton Aniline Company on the methods they employed, under guarantee that such information should only be used for government

[1] 74/H.E.T./139, 379; 74/Explosives/75; HIST. REC./H./1520/5; D.G.M.D./E/32: X237/21.

purposes. On 5 June, 1915, the firm undertook to erect plant within two months for the treatment of at least 15 tons of T.N.T. daily. The loss of the supply of purified T.N.T. from Ardeer consequent on the explosion there in July, 1915, made it still more imperative that new purifying factories should be at once provided,[1] and after first adapting a stand-by caustic soda plant at their own works at Silvertown for the purpose, Messrs. Brunner, Mond proceeded to build the new and much larger purification works at Gadbrook.

The first sod was cut at Gadbrook on 19 July, 1915, and installation of the plant began in November, 1915. The first unit was completed in February, 1916, a second unit (in which improvements were made on the first) on 12 July, 1916, and a third on 27 December, 1916. In planning the construction of the factory, special arrangements were made against fire risks, and in June, 1916, a magazine was added with a view to increasing safety. A further extension was a T.N.T. grinding plant added in May, 1917.

The method of purification used throughout at Gadbrook was that of alcohol washing, but after a disaster at the Silvertown works at the beginning of 1917, much experimental work was done on safer methods of purification, and a plant for water washing was installed at this factory. This, however, did not go beyond the experimental stage, for with the further development elsewhere of a sulphite purification process the method of purification by washing with water lapsed.

The factory was throughout operated by Messrs. Brunner, Mond. Originally the firm were in the position of contractors working for a management fee of 5*s*. per ton of product. On 22 August, 1917, after the destruction of the Silvertown works and of a contractor's factory at Hooley Hill, the Order in Council which had previously exempted T.N.T. trade factories from the main provisions of the Explosives Act, was repealed. In order to avoid the application of stringent safety conditions to the unique and urgent operations carried out at Gadbrook, the factory subsequently ranked as a Government agency factory for the purpose of safety conditions.

The capacity of the factory was 75 tons per day, *i.e.*, 525 tons per week. Output began in February, 1916, and by July, 1916, it had reached 200 tons a week. At the end of March, 1917, orders were given to double this rate, and still further increases were asked for in July, and at the beginning of December, 1917. The maximum output was reached in the week ending 14 December, 1917, when 510 short tons were purified, but with the labour then available 450 tons per week was the average output. In March, 1918, a reduced output was ordered, and from May to the date of the Armistice, when operations ceased, only 120 tons per week were required. In all 34,131 tons of crude T.N.T. were treated, from which 31,197 tons of pure T.N.T. were obtained.

As regards labour, soon after process work began, shortage of male labour led to the decision to employ women, and these were first

[1] 74/Explosions/75.

employed on 21 March, 1916. Great labour shortage was experienced in the spring of 1917, but this was relieved by a draft of 137 men from Avonmouth. During the winter of 1917-18, when production was at its highest, 1,050 operatives were employed of whom 52 per cent. were women.

The total capital expenditure, as estimated in July, 1918, was £195,000.[1]

H.M. Factory, Greetland.[2]

As part of the scheme which was developed in December, 1916, for extending the production of picric acid in the country, Messrs. Sharp and Mallett undertook to erect and manage a factory at Greetland (Yorks.) and an agreement was drawn up on the same lines as that for the Lytham Factory.[3]

Possession was taken under the Defence of the Realm Act of a very convenient site covering rather more than 15 acres on the river Calder, two miles from Halifax and close to Greetland station. The main road from Halifax to Huddersfield bounded one side, and the Lancashire and Yorkshire Railway the other, the railway embankment being sufficiently high above the site level to make the handling of raw materials simple and cheap. Thus, for instance, sulphuric acid could be run by gravity from tank-wagons to storage boilers, and thence to various parts of the factory. The site was owned by the Halifax Corporation, and by the Lancashire and Yorkshire Railway, and use was made of a few old buildings belonging to former tallow works.

Construction of the main works was begun at the end of January, 1917. Considerable difficulty was experienced in laying foundations, since the site was sandy and consisted of an old river bed. The task was eventually accomplished and the factory started work in August, 1917, delivering the first output in September.

Steady progress was made during the autumn, although the factory was never required to reach its estimated output of 80 tons. The lay-out was admirably planned for economy and efficiency, and the plant well designed and fitted, while during the factory's working various improvements in method and plant were developed with a view to the increasing of efficiency and safety, and the reduction of costs and labour figures. The cost of nitric acid production at Greetland was £1 per ton cheaper than that of any other nitric plant controlled by the Ministry, and in spite of the constant rise in wages and prices, the improvements evolved by the management and chemical staff considerably reduced the cost of picric. Though the processes in use at Greetland and Lytham were identical in theory and nearly so in practice, the average cost of raw materials per ton of picric acid produced was £28 less at Greetland. Production was accordingly continued in 1918, and in April the factory began delivering undried "service" picric for poison-gas manufacture to replace the "waste picric" formerly

[1] X235/47.

[2] HIST. REC./R/1122.7/18, 1122.7/6, 1122/45, 400/57; HIST. REC./H/1500/6; 74/Lytham/14.

[3] *See* below, p. 66.

used for this purpose. After the Armistice, production was stopped, but for some time the factory was engaged in drying wet picric and repacking stores which had deteriorated.

Considerable difficulty arose in obtaining sufficient labour, and in November, 1917, output was restricted by lack of workers. The scarcity was relieved after the closing down of neighbouring works at Copley and Wyke, and dilution was carried out to a considerable extent, the women proving quite satisfactory on the lighter kinds of work. In October, 1918, there were 339 employees, of whom 24·2 per cent. were women.

In June, 1917, the capital expenditure was estimated at £160,000, and by March, 1919, the actual expenditure was £183,600.

H.M. Factory, Gretna.[1]

The large and important propellants factory at Gretna was erected on a tract of marshy land forming the north coast of the Solway Estuary and stretching across the border. Gretna itself is only about 8 miles from Carlisle, but the site covered over 9,000 acres, and consisted of a strip of land, roughly 9 miles by one, lying between the Glasgow and South Western Railway on the north, and the Solway Firth and the River Esk on the south. It extended from Dornoch Village on the west, to Longtoun on the east, and was served not only by the Glasgow and South Western, but also by the Caledonian and the North British railways.

The initiation of the factory was due to the Munitions of War Committee, who, on 13 May, 1915, recommended that a largely increased production of some substitute explosive suitable for land service should be arranged, in order to free service cordite for the use of the Admiralty. At the request of the committee, Lord Moulton considered the practicability of establishing a new source for an output of 2,000 tons of propellant monthly, and in conjunction with Sir Reginald Sothern Holland, he drew up a plan for making the whole quantity in a single factory. On 27 May, 1915, he recommended that the new factory should make cordite R.D.B., which had just been evolved by the Research Department, and was made from the solvent ether-alcohol in place of acetone, of which supplies were short. During the month of June, preparations for the new factory were continued, and on 26 June, Mr. Lloyd George, as Minister of Munitions, gave formal authority for its erection. The main problem as regards site was to find an isolated area of sufficient size, with an enormous supply of water, suitable for explosives manufacture. Towards the end of June the site was fixed at Gretna, where a water supply of close on ten million gallons a day was eventually drawn from the River Esk. The area, first taken under the Defence of the Realm Act, in July, 1915, consisted of 7,715 acres of lightly-farmed arable and pasture land, and an additional 1,399 acres were subsequently taken. It was further decided that in addition to making up its own nitrocellulose

[1] Hist. Rec./H/1122.7/11, 17, 19, 25; Hist. Rec./H/346/5; Hist. Rec./R/172/1, 172/7, 263.5/5.

into cordite, the factory should be made capable of dealing with the nitrocellulose produced by H.M. Factory, Queen's Ferry, the total annual output expected being some 40,000 tons of cordite per annum, *i.e.*, about 3,300 tons per month, in place of the 2,000 tons per month originally proposed.

The actual lay-out and detailed planning of the factory was carried out at the Explosives Supply Department, under the personal direction of Mr. K. B. Quinan. The factory was divided into several "areas." That at Dornoch (area 1,203 acres) comprised the glycerine distillery, and the acids, nitrocellulose and nitro-glycerine sections. From the Dornoch Area, the paste was despatched eastward to the Mossband Area (1,381 acres), where it was made into cordite. In this area there were eight units or ranges widely dispersed for the sake of safety. Thence the finished cordite was sent to magazines in what was known as the Longtoun Area (258 acres). Not far from the Mossband Area, was a separate ether section which supplied the ether-alcohol solvent. The solvent recovered in the cordite section was returned to this ether section for distillation. The site (10 acres) chosen for the central electric power station was at Rigg, between the Dornoch and Mossband Areas, while the water intake and pumping station (5 acres) lay a short distance above Longtoun. Reservoirs and filters covered 14 acres. The above were all fenced areas patrolled by the military guard, and used for factory operations. The remaining land was used for the erection of townships and for agricultural and general purposes.

Agreements were made with various contractors and construction began in August, 1915. In the autumn of 1915, in order to expedite the erection of the factory, a large and experienced firm of contractors (Messrs. Pearson & Son, Ltd.) were entrusted with the entire direction and management of the construction and erection of the factory in accordance with the plans and designs provided by the Minister's technical advisers. They undertook this task with the title of "Construction Managers," and a measure of discretion substantially larger than is usual was conferred upon them in order to secure the requisite expedition. The various sections did not, of course, start up simultaneously. Among the earliest working were the Mannheim oleum plant (June, 1916), and the glycerine distillery and nitric acid retorts (July, 1916). Output of the final product from Gretna paste began in August, 1916, though the cordite ranges began to produce from Messrs. Nobel's paste two months earlier. The factory was controlled by the Factories Branch of the Explosives Supply Department, and was under the management of a superintendent.

The factory dealt not only with its own, but also with imported nitrocellulose. The capacity of the factory nitrocellulose plant was 350 tons per week, while the quantity of nitrocellulose to be imported was estimated at 200 tons per week. The nitro-glycerine necessary to mix with this was made from pure glycerine produced from imported crude glycerine at the glycerine distillery, which was the only State-owned plant for purifying glycerine. The capacity of the nitro-glycerine plant was 800 tons per week, and that of the glycerine distillery was

240 tons per week. The nitric and sulphuric acids necessary for consumption were made in the acids section, nitrate of soda, pyrites and sulphur being imported for the purpose. The sulphuric acid (in the form of oleum) was made by the contact process on both Mannheim and Grillo plants, the capacity of the former being 280 tons SO_3 per week and of the latter 560 tons SO_3 per week. The nitric acid retorts were capable of producing 800 tons HNO_3 per week. The acids section also included the plant necessary for denitration, concentration and acid mixing. The capacity of the ether plant, which produced ether from imported alcohol, was 1,570 tons a week. Although the factory was planned with a view to an output of 800 tons of R.D.B. cordite per week, it was capable of a maximum output of 1,000 tons per week. The full output of 800 tons per week was attained early in 1917, and the total output from the opening of the factory to 28 January, 1919, was 56,876 tons.

It was estimated in June, 1915, that the factory was likely to employ between 10,000 and 15,000 workers. Since it was impossible to find neighbouring accommodation at Carlisle and elsewhere for such a number, the decision was made to erect factory townships. The Local Government Board was consulted by the Explosives Department, and the townships were planned by Mr. Raymond Unwin, chief town-planning expert of the Local Government Board, whose services were borrowed for the purpose. The two principal townships were Gretna (area, 431 acres) in the central part of the factory area, and Eastriggs, near Dornoch (area, 173 acres) on the western extremity of the factory area. At both of these townships, churches, schools, public halls, post offices and shops were provided. Some houses were also erected at Gartleburn, Mossband and elsewhere. The development of this entirely new community and the organisation of its social life have been described elsewhere.[1] Originally, large numbers employed on construction were housed in the townships and the staff and operatives of the factory did not come into full possession till August, 1917. The maximum number of construction and operating workers employed together was 24,000. The maximum number of operating workers employed was 19,772 (October, 1917), but the efficient organisation resulting from experience made it possible to economise labour and the number working in October, 1918, including staff, was 11,511.

The problem of female labour at Gretna was unique. The proportion of female to male labour was about 70 per cent. to 30 per cent. in the summer of 1917, but at the time of the Armistice, the number of women had decreased to 60 per cent. of the whole. There was no possibility of drawing the full number of women required from the locality, and between five and six thousand had to be brought from all parts of the country. This necessitated special "welfare" organisation, not only in the factory itself, but also in the factory townships.

The estimated expenditure, including the cost of the housing scheme, as calculated in November, 1915, was £2,000,000, and in August,

[1] Vol. V, Part V, Chap. VIII.

1916, it was £5,000,000. The actual expenditure far exceeded that sum. Treasury sanction was obtained for £8,500,000 in June, 1917, and the actual cost of the factory and townships down to 31 March, 1919, was £9,295,200.

H.M. Factory, Hackney Wick.[1]

This factory, formerly known as the Phœnix Chemical Works, White Post Lane, Hackney Wick, covered an area of 9,174 sq. yds. The nearest goods station was three-quarters of a mile distant, and the water supply was obtained from the River Lea. It was originally operated by a contractor, Mr. D. Bagley, under an agreement negotiated in October, 1914. He purchased the works on 29 January, 1915. The War Department undertook to advance the capital for this purchase and for the adaptation of the plant; to supply, free, the raw material for T.N.T. production, in quantities based on the supervisor's report during the third, fourth and fifth weeks of production; and to pay a fixed price of 3*d.* per lb. of T.N.T. produced and delivered under contract, plus the cost of material used by the contractor, a price being fixed for nitric acid and toluol. The factory and plant were to be the property of the contractor, charged with repayment of advanced capital, plus 5 per cent. per annum, but if he fulfilled all his obligations the interest was to be waived. Production was to begin within 3 months of the agreement, and the ultimate capacity of the plant was estimated to be not less than 15 tons of T.N.T. per week, and sufficient nitric acid for the T.N.T. manufacture. The works were originally laid out for the French method of production and afterwards modified to use the Research Department process No. 1. At the end of June, 1915, no output had been obtained, and the Explosives Supply Department, ascribing the failure to the contractor, took over the factory on 9 July, 1915. Purchase of the factory was considered preferable to seizure under the Defence of the Realm Act, as this would have entailed restoring to the contractor after the war, works in which he had invested no capital, and the change in process upon which the Department had insisted, prevented the enforcement of a penal clause. The purchase was completed on 10 June, 1916.

The first unit began output towards the end of July, the second, on 2 October, 1915, and from that date a steady progress was maintained; 84 tons of T.N.T. were produced during December, 1915. The maximum capacity was estimated in April, 1916, at 25 tons per week, and the nitrating plant was subsequently extended in order to bring the capacity up to 35 tons weekly.

Labour was principally male, and in January, 1917, only 13·8 per cent. of the total (189) were women.

In April, 1917, it was decided to close the factory on account of the congested area in which it was situated, but to keep the plant in condition as a stand-by factory.

The capital advanced under the contract of 29 December, 1914, was £24,000, and an additional sum of about £16,000 was sanctioned

[1] 74/B./38; 74/B./368; C.R. 2913; (Printed) *Statement of T.N.T. Contracts February*, 1915.

by the Treasury on 24 September, 1915, for change in process. The purchase money paid by Mr. D. Bagley for the works amounted to £6,000, plus £75 for fittings. The additions and alterations finally made, brought the actual cost of the factory up to £66,200, by March, 1919.

H.M. Factory, Irvine.[1]

H.M. Factory, Irvine, was laid down in order to provide a British source of supply for nitro-cellulose powder of the American type and so reduce large overseas purchases which were undesirable on account of the financial situation. The construction of a much larger factory for the production of nitro-cellulose powder at Henbury was planned contemporaneously.

The site of the Irvine factory, covering 222 acres, was acquired in the latter part of 1916, from the Duke of Portland at a yearly rental of £750. It was situated three-quarters of a mile to the south of the Burgh of Irvine, and was bounded on the east by the Glasgow and South Western Railway, the proximity of this railway greatly facilitating the transport of goods and workers. The water supply for the factory was drawn from two sources, namely, the waterworks of the Irvine and District Water Board, and also the works of the Troon Corporation at the Collenan Reservoir. Electric power was supplied to the factory from the works of the Kilmarnock Corporation situated five miles distant.

Building operations were started in January, 1917, but the work of construction was not hastened as the entry of the United States into the war on 6 April, 1917, materially altered the situation. Importing the finished product from America involved considerably less tonnage than importing the necessary raw materials, and the shipping position was becoming increasingly grave. Accordingly the construction of the factory at Irvine was only proceeded with slowly under low priority, while the Henbury scheme was entirely abandoned.

H.M. Factory, Irvine was erected and operated under an agency agreement with Nobel's Explosives Company, who had a working arrangement with the Du Pont de Nemours Powder Company of America that all processes should be worked in common, a royalty being paid on those perfected after July, 1914.[2] They and one other firm had previously made small quantities of nitro-cellulose powder for foreign States, and with this one exception, no other firm in this country had had any experience in the production. In June, 1917, Du Pont de Nemours agreed that so long as existing conditions continued the British Government might make their improved form of nitro-cellulose powder free of royalty. The factory was laid out for the production of 100 tons per week of ordnance powder and 50 tons per week of rifle powder. The manufacturing plant was arranged in three sections namely, acids, nitro-cotton and powder. Parts of the plant and processes were arranged on lines following the latest American practice and hitherto not used in this country, and many difficulties directly connected with the novelty of the plant were encountered during the

[1] HIST. REC./H/1122.7/8; HIST. REC./R/1530/11. [2] X235/35.

initial stages of manufacture and gradually overcome. Work began in February, 1918, with the re-conditioning of some lots of American nitro-cellulose powder damaged in transport, and ordinary service production began in April. Although substantial progress was made, maximum output was not reached at the cessation of hostilities, when instructions were given to cease operations. The total production of the factory for the period during which it was working was 118 tons of reconditioned powder, 926 tons of cannon powder and 140 tons of rifle powder.

As the factory was situated in the centre of a busy industrial district, an adequate supply of labour was obtainable and it was not necessary to inaugurate housing schemes. The greater part of the process work was carried out by women, but the supervising staff were entirely men and no dilution of skilled trades labour was undertaken, *e.g.*, among plumbers, fitters, joiners, etc. The numbers employed in October, 1918, were 1,568; the percentage of women being 73·2.

The total outlay upon the factory to 31 March, 1919, was £953,200.

H.M. Factory, Langwith (Mansfield).[1]

A factory for the manufacture of ammonium perchlorate was constructed at Langwith on ten acres of land rented from the Langwith By-Product Company, Ltd. Langwith is approximately 8 miles from Mansfield on the Midland Railway, 20 miles from Nottingham and 26 miles from Sheffield. The site was chosen largely because of the existence, contiguous to the pits of the Sheepbridge Colliery, of a Mond gas recovery plant owned by the Langwith By-Products Company from which gas and ammonium sulphate might be obtained. The decision that the factory should be constructed, in order to secure independence of Sweden for the supply of ammonium perchlorate, was made in 1915. France, with Sweden, had been a source of supply at the outbreak of the war but the output of the former had been rapidly absorbed by her own demands. The process developed and owned by a Swedish firm was adopted and a contract for the use of the process on a royalty basis was entered into in September, 1915. Contracts were also executed with the Langwith By-Products Company for the production of gas and bye-products and with the National Gas Engine Company for the construction of an up-to-date gas engine plant. The Power Gas Corporation were appointed consultant engineers on the power plant.

The process involved the electrolytic conversion of common salt to sodium perchlorate and the chemical production of ammonium perchlorate from this latter product by double decomposition with ammonium sulphate. Sodium sulphate in the form of Glauber Salt was to be produced as a bye-product from the chemical operation.

The excavations and buildings were begun in November, 1915. The first load was taken in the electrolytic section on 29 October, 1916. Running difficulties arose, however, at the very outset in the

[1] *H.M. Factory, Langwith*; 74/S./159, 246, 314; 74/Langwith/3, 4, 8, 10, 14, 21, 50, 162, 216.

electrolytic section, and later in the chemical section, and output did not begin till June, 1917. The administration of H.M. Factory, Langwith, differed originally from that of other government factories managed from headquarters, as regards the position first of the Power Gas Corporation as consulting engineers and then of the construction manager appointed. In July, 1917, however, a reorganisation of the staff took place and a superintendent was appointed. From this time the management of the factory was in line with that of similar factories controlled directly from headquarters.

The factory was laid out to produce 3,000 short tons of ammonium perchlorate per annum or 50 long tons per week. The original output beginning in June, 1917, was very small. At the end of August, a new process for the chemical section of the manufacture was discovered which simplified and reduced the number of stages.

By the end of September, this was in actual operation, but it took some time to work out all the details of practical running, and the progress was interrupted by two explosions attended by fatal results. In July, 1918, full output was reached, and from July to November the average output was well over 50 tons per week. The total output from June, 1917, to 14 December, 1918, was 2,173 tons of ammonium perchlorate.

There was some scarcity of labour and this helped to retard construction. As regards dilution of labour, women did not replace skilled men except in the case of acetylene welders, but they were used successfully in both semi-skilled and unskilled work. In September, 1918, of 705 employees, 372 (52·7 per cent.) were women.

The workers were drawn from a radius of 8 miles, served almost entirely by the Midland Railway Company. A government village was erected half a mile from the factory on 5½ acres of land taken under the Defence of the Realm Act. It housed those of the staff and operatives whom it was necessary to have within reach of the factory. The actual capital expenditure down to 31 March, 1919, was £717,400.

H.M. Factory, Litherland (Liverpool).[1]

The explosive factory at Litherland was established as a trade venture in November, 1914, by Messrs. Brotherton & Company, a firm of tar-distillers with a command of large toluol supplies. It was set up on ground adjacent to the company's own works, and derived power from the same steam-generating plant. Lying 4½ miles to the north of Liverpool, the site was connected by sidings with the Lancashire & Yorkshire Railway, and a densely populated area to the south-west afforded an excellent labour field with convenient housing accommodation. The land originally occupied subsequently proved inadequate and additional ground was acquired at intervals, bringing the final area covered by the factory to more than 11 acres.

The factory was intended to meet the whole demand for T.N.T. for filling small natures of shell for the 1915 campaign, viz., some 500,000

[1] Vol. X, Part IV, Chap. IV ; 74/B/372, 486 ; C.R. 2913 ; 74/Litherland/30. 60, 156 189.

pounds, and delivery was promised between December, 1914, and September, 1915. After construction had begun, however, it was considered impossible to bring so large a plant into operation in so short a time, and in March, 1915, a government representative was appointed to expedite the starting up of the factory. In view of the urgent demands for T.N.T. he was authorised to increase the capacity of the works from 50 to 100 tons weekly by ordering additional plant at the expense of the State, and to exercise a general supervision over the management at the factory. This arrangement proved impracticable owing to the indefinite relations of the Ministry's official to the firm, and the difficulties inherent in divided control. Repeated delays occurred in the course of equipment, the recommendations of the Department were neither thoroughly nor quickly carried out, and by the spring of 1916 the output was rarely more than 20 tons weekly. The inadequate supply of steam was a source of trouble for some time, but was partially remedied later by the introduction of fuel economisers and the substitution of electric motors where possible. In March, 1916, the Department took over the direct control of the factory, and there followed a period of re-organisation and expansion. The 50 tons output of the original estimate was reached in July, 1916, but progress was hampered by a shortage of nitric acid due to the ill-balanced lay-out of the plant, while in November, 1916, when it was decided that the T.N.T. must be granulated, new plant was required for the purpose. During the winter a further re-organisation of the management took place, and the output was not raised to 100 tons weekly until June, 1917. Even at this date the Superintendent did not consider that the rated output could be maintained, in view of the unsatisfactory condition of the plant. The failure of the concentration plant to absorb nitric fumes gave rise to various complaints in the neighbourhood, and made working conditions so bad that in 1918 the earlier difficulties were enhanced by a shortage of labour. The process in use was that of nitrating in three stages, and involved extensive handling of the material. When the numbers employed were too few to cope adequately with the work mishaps frequently occurred, and the machinery was so constructed that repairs required in any part delayed all the process, while the inadequacy of intermediate storage caused delay in any section to affect the whole output. In the earlier stages of the factory's operation dilution was difficult to effect owing to the scarcity of competent supervisors and forewomen. At the date of nationalisation the proportion of women to men was very small, and in July, 1917, was only 66 to 434, but the number was gradually increased until in March, 1918, the female labour formed 33 per cent. of the whole number employed (807).

In April, 1918, when the shell-filling programme was reduced, instructions were sent to the factory to close down, and after using up the materials in stock, and cleaning plant, the workers were paid off in the following month.

The estimated outlay on the factory was £198,000, and by March, 1919, the actual expenditure was £185,000.

H.M. Factory, Lytham.[1]

In December, 1916, when efforts were made to increase as much as possible the supply of picric acid, three new national factories were planned to utilise a quantity of the raw material, phenol, which was then available. Each was to be managed by a firm which had already proved a satisfactory contractor, and was to produce 80 tons weekly. An agreement was drawn up with each firm, the main points being identical for all the factories. By this agreement the firm undertook to erect and equip the factory in the shortest possible time in return for a fixed sum (in the case of Lytham, £2,000), to appoint and train the necessary staff and to manage and secure the efficient working of the factory in return for a remuneration calculated at the rate of $\frac{1}{10}$d. for each pound of picric produced, provided that a minimum sum of £2,000 should be paid in any year. The Ministry was responsible for all costs, either of construction or production, and either party could terminate the agreement on one month's notice.

The first of the three factories to be started was at Lytham under the management of Mr. Lance Blythe. It had been intended to build this factory at Blackburn, but owing to the difficulty encountered as to railway facilities, the first site was abandoned in favour of a more convenient site at Lytham. The land was about 21 acres in area, level, and fairly low, but free from any possibility of flooding, was adjacent to the manager's works, and could use the railway sidings constructed between them and the Lancashire and Yorkshire Railway; a good water supply was available, and the site was sufficiently isolated to render very remote the possibility of any danger to local inhabitants, in case of accidents. Possession was taken immediately under the Defence of the Realm Act, and an annual rent was paid to the owner.

Mr. Lance Blythe acted as manager of the factory until November, 1917, when, as his previous undertakings prevented his devoting as much time to Lytham as was necessary to efficient supervision, the factory was placed under the immediate control of the Factories Branch of the Explosives Supply Department.

Construction began towards the end of January, 1917, and was vigorously prosecuted, practically all the buildings, and much of the plant, being erected in April. The plant was laid down to ensure the continuous conversion of 50 tons of phenol per week into picric acid, and was complete in respect to the manufacture of the necessary nitric acid, the concentration of waste sulphuric acid and the neutralisation of the effluent from the works. Production began by 28 July, 1917. The output increased steadily through the summer, from 15 tons weekly early in August to 55 tons in October, and the designed output of 80 tons was reached by 10 November, 1917. At the end of the year, when the programme of picric acid production was reduced, the less economical factories were closed down, and Lytham ceased production in March, 1918.

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[1] 74/Lytham/1, 14, 16; (Printed) *Weekly Reports;* Hist. Rec./H/1500/6; Hist. Rec./R/1122.7/6, 1122/45, 400/57. M.W.L.S. 32355/3.

Some difficulty was experienced in obtaining labour, though additional workers were brought in from Preston and Blackpool, a special station being built for the factory. The plans of the factory allowed for the employment of 250 men and 50 women, but by August, 1917, no women were employed. Difficulty was anticipated in obtaining women workers owing to the high wages paid by the cotton mills. The management, whose general feeling was against the employment of women, did not intend to appoint any until they were absolutely obliged and considered the work, except in the drying and packing rooms and on trucking, unsuitable to them. Some girls were at work, however, by November, 1917, and at the end of the year women formed 31·6 per cent. of the total number (358).

The working costs of the factory were comparatively high owing to the relatively large amounts of raw materials consumed. The average cost for raw materials per ton of picric produced was £175 per ton at Lytham as against £147 at Greetland, giving an excess expenditure when the factory was working to its full capacity of roughly £100,000 per annum.

The capital expenditure was estimated in December, 1917, at £180,000; the actual capital expenditure by March, 1919, was £166,800.

H.M. Factory, Oldbury.[1]

The first national factory for T.N.T. production was erected at Oldbury early in 1915. It consisted of two main units. The one contained plant for nitric acid and oleum manufacture and acid recovery. The other consisted of installations for storing and treating toluol-benzine and nitrating it through M.N.T. up to T.N.T. and also for making T.N.T. from coal-tar toluol. This unit was placed for safety at a distance of 2,000 ft. from the acid plant, which was adjacent to the works of Messrs. Chance and Hunt, a well-known firm of acid manufacturers. The one site was within 200 yards of Oldbury goods station, the other was adjacent to Langley Green Station on the Great Western Railway. The factory was also served by the Titford Canal. The two sites occupied rather more than 18 acres. From time to time extensions were made for various purposes, *e.g.* for box-making and repairing, the total area finally occupied being over 39 acres.

Messrs. Chance and Hunt had first been approached by the Committee on High Explosives in December, 1914, with a view to extending their output of acids, particularly nitric acid. Work on extending their nitric acid plant began 21 December, 1914. This acid scheme was secondary to a project for erecting a factory to make 50 tons of T.N.T. weekly, negotiations for which began in December. Under an agreement of 11 January, 1915, the Explosives Supply Branch of the War Office undertook the responsibility for the lay-out of this plant, which was to be erected by the firm at the expense of the State. The Department was to operate the T.N.T. factory during a preliminary

[1] C.H.E./2553; 74/Q./3; 74/C/76, 79; 74/H.E./4, 22; 74/Oldbury/127; 74/H.E.T./234; HIST. REC./R/1500/2, 3, 6; HIST. REC./R/1500/14, p. 107.

experimental period and then to transfer it to the firm, whose property it was to become. The firm was thenceforward to operate the plant and deliver T.N.T. under contract, the basic material M.N.T. being provided by the Department.

This agreement was based on the treatment of 30 tons of M.N.T. weekly, the quantity then available for the purpose. It was superseded almost immediately by an expanded project for making between 700 and 1,000 tons of T.N.T. monthly along the lines of the Research Department's two-stage process, worked out about 19 January, 1915, and from toluol-benzine produced at the Portishead distilleries. Arrangements for removing these distilleries from Rotterdam to Portishead were made with the Asiatic Petroleum Company in January, 1915, and the company also engaged to erect at Oldbury plant for treating the toluol-benzine and converting it into M.N.T. When this plant had been brought to efficiency, it was transferred to the Department's representative and became an essential unit of the Oldbury factory.

The lay-out and erection of the T.N.T. factory were controlled by Mr. K. B. Quinan, General Manager of the Cape Explosives Company, whose services were lent by the De Beers Consolidated Mines Company. Mr. Quinan was summoned from South Africa on 18 December, 1914, for this purpose, and arrived in England on 5 January, 1915. Work on the T.N.T. site began on 8 January, 1915, and was carried out with great expedition. The M.N.T. plant was completed by the end of May, and the T.N.T. plant started production in that month. Pending construction a new agreement was negotiated with Messrs. Chance and Hunt, which resulted in the establishment of the nitric acid, M.N.T. and T.N.T. works, together with the oleum plant, as a national factory under the control of the firm as agents of the Crown. The details of the new contract were not settled until the end of April, 1915, but its terms were retrospective as from 1 February. It provided that the Department should be responsible for the lay-out and erection of the installations, the agents assisting in providing labour and materials, etc.; that plant should be installed at state cost and should remain the property of the State; that the sites should be leased by the firm to the Department with certain options as to purchase, and that the agents should operate the factory at Government expense, assisting the Department in the purchase of materials other than toluol, toluol-benzine, or M.N.T. In addition to certain sums already paid towards the cost of acid extensions under the earlier agreement, the firm received a fixed weekly payment during the period of erection and thereafter a weekly payment per lb. of T.N.T. produced, the scale of payment decreasing with certain increases in output. Manufacture was to be from sulphuric acid produced at the firm's neighbouring works and purchased at market prices based on the cost of sulphur. Certain minimum quantities of nitric acid were also to be purchased from the firm's neighbouring works at prices based on the cost of sodium nitrate. Under the new agreement, the oleum plant was erected on the acid site rented by the Department and not within the firm's works, as had been the original intention. Small-scale output began in May,

and from the end of July, 1915, over 50 tons of T.N.T. was produced weekly, and in November, 1915, the factory reached its full output of 130 tons weekly. Much valuable research work was done in the laboratories, where a new continuous process was evolved. This method was introduced into the factory in October, 1917, and enabled the original installation to increase its output five-fold with only slight structural alterations.

The number of operatives engaged in the factory in August, 1917, was 1,749, and in October, 1918, 2,116. The percentage of women employed in both sections increased gradually, was greatest in the T.N.T. section, and was always considerably below 50 per cent., the figure in October, 1918, being 36·7.

The capital expenditure down to March, 1919, was £835,300, of which £60,000 had been the estimated cost of the alterations for installing the new process in October, 1917.

H.M. Factory, Pembrey.[1]

This factory, situated on the Pembrey Sand Burrows, near the village of Pembrey, in Carmarthenshire, covered an area of about 760 acres and comprised over 400 working buildings for the production of T.N.T., tetryl, cordite, and ballistite. The Great Western Railway main line from Paddington to Fishguard ran within three-quarters of a mile of the factory, with which it was connected by two branch lines. A private road, 15 ft. wide, afforded facilities for motor transport to the main Swansea to Carmarthen road. In October, 1914, Nobel's Explosives Company, Ltd., of Glasgow, agreed with the Secretary of State for War to erect and manage a T.N.T. factory at Pembrey, upon the site where they had intended to set up works for making industrial explosives. By the contract drafted in February, 1915, the State was to supply toluol free of charge, and to pay seven-tenths of the capital expenditure; the entire output was to be delivered to the Explosives Loading Company's filling factory at Pembrey. The firm was also under agreement to manufacture at Pembrey propellant explosives for the Admiralty, and in October, 1915, the two agreements were amalgamated and transferred to the Ministry of Munitions. It was then agreed that the State should bear the whole cost of the plant, which should remain Government property after the war, and that after 31 December, 1916, the factory should be operated by Messrs. Nobel on behalf of the Ministry. Supervision was accordingly transferred to the Factories Branch of the Explosives Supply Department on 1 January, 1917, and Messrs. Nobel were retained as agent managers. The original agreement stipulated for the production of T.N.T. and the erection of the necessary acid plant. The work of construction proceeded immediately, and T.N.T. manufacture began in July, 1915. In this same month the Admiralty finally arranged with Messrs. Nobels to erect additional plant at Pembrey for the manufacture of M.D. cordite paste from guncotton supplied from outside sources. The work was put in hand in September, 1915, and the unit was completed by January, 1916, when the production

[1] X235/39; X236/34; 74/N./45; 74/N./61; 74/Pembrey/116; C.R. 2913.

of cordite paste began. A further extension for the production of propellants was effected at the instigation of the Ministry of Munitions, and in October, 1915, the plant was installed for the manufacture of ordnance cordite, rifle cordite, and ballistite. These extensions included sections for the production of guncotton and nitro-glycerine, and extensive additions to the water, steam-power and general service supplies of the factory, which by March, 1916, was producing ballistite and rifle cordite, and by May ordnance cordite. The tetryl plant which had been erected in the autumn of 1915 was in operation by the end of that year. The buildings were arranged in progressive order, raw materials, stores and acid plants being convenient for railway facilities. A safety zone of about 400 yards lay between the T.N.T. and propellant explosives section, and was kept free from buildings.

The factory was originally intended to produce 60 tons of crystallized T.N.T. per week, but later crystallization was abandoned, and the plant altered to produce crude T.N.T. at the rate of 200 tons per week. A further extension increased the capacity to 300 tons weekly. The output of M.D. cordite paste was 200 tons weekly. The propellant section was first planned for the production of 150 tons of ordnance cordite, 40 tons of rifle cordite, and 15 tons of ballistite per week. A further extension of the ordnance cordite plant increased the capacity to 225 tons per week, and when the workers were trained the output rose to 300 tons weekly ; but the acid plant was not capable of keeping both the T.N.T. and the cordite plants supplied when they were working to their full capacity.

No public services being available, the factory had to be self-contained and plant was established for supplying water, electric light, power and steam. The water supply was obtained from two small rivers five miles away ; intake ponds were constructed, from which the water was carried in 15 in. mains to a low-level pond in the factory, where it was chemically treated, filtered, and pumped to high-level storage tanks, from whence mains were carried throughout the factory. The daily consumption of water was approximately 4,000,000 gallons. Steam was generated at four boiler stations having 33 boilers, capable of producing 5,000,000 lbs. of steam per day. Electric light and power were generated at the factory power station, where seven generators with a total capacity of 4,300 k.w. were installed.

The supply of local labour being insufficient, the majority of the operatives were drawn from Llanelly, and later from Carmarthen and Swansea. They were conveyed to the factory gates by special trains free of charge. All workers were paid at an hourly rate, according to the class of employment. Female labour was introduced into all departments—in acids 10 per cent., T.N.T. 80 per cent., cordite 76 per cent., guncotton 95 per cent., and general labour 30 per cent. The total number of employees in October, 1918, was 4,765, of whom 58·6 per cent. were women. .

The site was held on a lease of 99 years at a yearly rental of £1,800. On 28 June, 1917, the Treasury sanctioned an expenditure of £2,600,000, and the actual expenditure to March, 1919, was £2,850,600.

H.M. Factory, Penrhyn Deudraeth.[1]

This factory, situated on the Welsh coast, a quarter of a mile from the goods station, covered an area of 11 acres. It was built by the Ergite Company under a contract to supply T.N.T. to the Admiralty, who bore a considerable part of the cost. In June, 1915, the crystallizing station, workshops, office, laboratory and acid mixing section of the nitration plant were destroyed by explosion, and the Explosives Supply Department undertook to reconstruct the premises as a Government factory, appointing a construction manager for this purpose. No compensation was to be paid to the Ergite Company, but settlement was to be made when plant was handed back. The factory was laid out for the second continuous process of crude T.N.T. production, and was the only one where this process was actually worked, the waste acids being discharged into the sea. In 1917 an important change in the process was adopted, based on the desirability of utilizing still residues after T.N.T. purification. The necessary plant was erected, and it was hoped to recover an amount of T.N.T. equal to 50 per cent. of the total residues so treated, by washing with sodium nitrate; previously these residues had been burnt.

The intended output in December, 1915, was 30 tons per week; the actual output during the month of February, 1916, was 63 tons, during December 148 tons, and in March, 1917, six tons daily. This last average was subsequently maintained. In 1916-17 the labour employed was principally male, the average number being 335 weekly. In October, 1918, of 349 employees 21·5 per cent. were women.

The Treasury sanctioned an expenditure of £67,000 upon this factory on 28 June, 1917. The actual outlay, including the cost of additional plant to increase output, amounted to £83,000 by 31 March, 1919.

H.M. Factory, Queen's Ferry with Sandycroft (Chester).[2]

H.M. Factory, Queen's Ferry, stands on 298 acres of land on the main London and North Western Railway line, from Chester to Holyhead, at a distance of about eight miles from Chester. The River Dee borders it on the northeast. The lease of part of the land was purchased under agreement, and the remainder was taken over under the Defence of the Realm Act. The original scheme provided only for the manufacture of guncotton, an acids section being included to render the factory self-contained. The functions of the factory were, however, increased, and T.N.T. and tetryl sections were eventually added, and also a Grillo oleum section, which made it possible to provide acid for export in addition to supplying the factory requirements. The areas of the various sites were as follows:—Guncotton section, 37 acres; T.N.T. acids, T.N.T. and tetryl sections, 99 acres; Grillo oleum section, 42 acres; M.N.T. section, 120 acres.

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[1] HIST. REC./H/900/9; 74/H.E.T./166.
[2] HIST. REC./H/1122.7/1, 1122.7/10; HIST. REC./R/1122.7/5,1122.7/15.

The factory owed its origin to the anxiety felt by the Admiralty at the beginning of 1915 as to the supply of cordite. The derelict engineering works of Messrs. Williams and Robinson at Queen's Ferry were secured on behalf of the Admiralty at the end of March, 1915, as being readily adaptable for the manufacture of guncotton. The original intention was that the factory should be controlled by the High Explosives Branch of the War Department and its output of guncotton sent for conversion into cordite at the new State factory, then being erected by the Admiralty at Poole. At first plans were made for an output of 100 tons of guncotton per week, but this was later increased to 200 tons. It was not possible to obtain full and immediate possession of the site in order to press on with the adaptation of the works, as German prisoners interned in the buildings were not removed until 14 May. At the end of that month the Admiralty, in order to increase its autonomy in regard to propellant supply, notified that the output from Queen's Ferry would not be needed for naval purposes. The factory was thereupon accepted by the Secretary of State for War for the use of the Army and was transferred to the Minister of Munitions at the end of June. Since the guncotton it was to produce could not be used until the nitro-glycerine and cordite factories, then under discussion, were planned and erected, it became unnecessary to force the speed of construction, and part of the energy available was diverted to the erection of T.N.T. and tetryl sections, the construction of which was decided upon to meet the extended shell programme of July, 1915. In conjunction with this extension the Asiatic Petroleum Company proceeded to build a factory for the production of M.N.T. at Sandycroft on a site lying at the south-east end of the T.N.T. section. This factory was subsequently (in June, 1918) incorporated with H.M. Factory, Queen's Ferry, under the designation of the M.N.T. section. Simultaneously with the drafting of the designs of the T.N.T. and tetryl sections, plans were prepared for a Grillo oleum section. In August, 1915, it was decided also to produce dinitrobenzine, but this project was later abandoned.

The designing, purchasing and erection of the plant was in the charge of Mr. K. B. Quinan of the Explosives Supply Department. The actual construction work was undertaken by contractors, the agreements being of the cost plus percentage type. This form of agreement was necessitated by the fact that the details of the lay-out were settled during construction. The factory was directly controlled by the Factories Branch of the Explosives Supply Department. It was put under the management of a superintendent.

The work of reconstruction on the guncotton section and of construction on the guncotton acids section and boiler house was begun in May, 1915. As soon as sufficient plant was installed, manufacture was begun and finally, on Christmas Day, 1915, the first batch of wet guncotton was packed and ready for dispatch.

Construction on the T.N.T. acids section was begun in September, 1915, the Mannheim oleum buildings being the first to be proceeded with. The first unit of this plant was producing in January, 1916. The first T.N.T. unit was producing by 21 March, 1916, and thereafter

unit after unit of the T.N.T. and T.N.T. acids sections was brought successively into operation until in the month of October, 1916, all the T.N.T. units—5 in number—were operating.

The construction of the tetryl section was commenced in October, 1915, at a time when the supply of tetryl was very limited. The original intention, therefore, was to push on with construction as rapidly as possible, and to complete the plant by the end of January, 1916. The immediate need having disappeared, owing to changes in design of detonating apparatus for H.E. shell, the work of construction proceeded more slowly and was not completed until the end of May, 1916. At first the plant was mainly employed for the investigation of various points of importance in the manufacture of picric acid, and it was not until November, 1916, that the production of tetryl was commenced.

Construction on the Grillo oleum site was begun in December, 1915, the first unit coming into operation in September, 1916. The last of the ten independent units came into operation in May, 1917.

On the M.N.T. section, construction work under the Asiatic Petroleum Company was begun in August, 1915, and production commenced in January, 1916. The principal units of this section were completed six months later.

The output of the guncotton section was for the first seven months of its running service guncotton, and during this period a total of 2,163 tons was manufactured. In August, 1916, a change was made to the manufacture of the lower nitrated form of nitrocotton required for the production of R.D.B. cordite at Gretna. From that time until March, 1918, when the plant was closed down owing to a change in the explosives programme, a total output was achieved of 15,907 tons of nitro-cellulose. The capacity of the plant towards the end of its period of working was about 250 tons a week, these figures being on a dry basis.

The M.N.T. plant consisted of three distinct units, each with an approximate capacity of about 450 tons per week, two of them being designed for working on toluol benzine while the third was specially adapted for the nitration of pure toluol. During the period of operation of the plant over 37,000 tons of M.N.T. were produced for consumption on the T.N.T. plant.

The T.N.T. plant consisted of five units, each consisting of nitration, and washing, drying and packing houses. Each nitration house could be reckoned as having a capacity of 150 tons of T.N.T. per week. Most of the T.N.T. produced at Queen's Ferry was Grade III, but out of the five wash houses, one was fitted, in January, 1918, with the plant necessary for purifying by the sulphite process crude T.N.T. of high setting-point, with a view to obtaining Grade II T.N.T. This process was later modified to permit of the production of Grade I T.N.T. A second wash house was later converted to sulphite process. The capacity of each sulphite house was about 180 tons per week, and of each of the other wash houses 200 tons per week. When the erection of the T.N.T. section was first under discussion, the proposal was for an output of 200 tons per week, but in designing the plant considerable

margin was allowed as regards capacity, and ultimately Queen's Ferry became the biggest T.N.T. producer in the country, reaching a maximum output in 1918 of over 700 tons per week. During the two and three quarters years of operation the total T.N.T. production was 115 tons of Grade I, 5,572 tons of Grade II, and approximately 50,000 tons of Grade III.

The manufacture of tetryl was commenced in November, 1916, the total output, reckoned as crude, being about 460 tons. Nitration was started before the purification plant was ready in order to test the plant and to augment the supplies of crude tetryl. The purification of crude tetryl by means of acetone was introduced in September, 1917, and after the destruction of the Waltham Abbey plant the Queen's Ferry plant was put on full output and became the sole source of supply of Grade I tetryl, the total output being 160 tons. In order to set free acetone for other purposes nitric acid was suggested as a substitute in tetryl purification, and large scale experimental work was carried out at Queen's Ferry. As a result, the nitric acid purification scheme was brought into operation in June, 1918, and in all produced about 214 tons of Grade Ia tetryl. The final capacity of the plant was 25,000 lbs. of purified tetryl per week.

The Acids Section supplied the acids necessary for nitro-cellulose, T.N.T. and tetryl manufacture. It comprised nitric acid retorts, denitrating columns and stills for dealing with spent acid, Gaillard towers, cascades and Gilchrist concentrators, acid mixing plants and Mannheim and Grillo oleum plants. Of these last, the Grillo plant proved easily capable of supplying all the requirements of the factory, and after its completion the Mannheim plant, which in early days was the sole internal source of SO_3 available for the factory, was only kept in operation when the urgent need of oleum for export to other factories necessitated it. The Grillo plant was capable of producing 1,500 tons of SO_3 per week, its total output being about 106,000 tons. The Mannheim plant had a capacity of 420 tons SO_3 per week with a total output of 19,700 tons.

Besides these main products, H.M. Factory Queen's Ferry also supplied a small quantity of trivelene (2–4 di-nitro-toluene) for which there was a demand early in 1918, a unit of the M.N.T. section originally intended for the nitration of D.N.B. being adapted for its manufacture. Shortly before the signing of the Armistice work began upon certain chemical mixtures. Experimental work was also carried out on the manufacture of T.N.T. X, with a view to establishing a satisfactory method of utilizing the stocks of xylene in the country, and also on the manufacture of chlor-sulphonic acid.

The factory was situated in a non-industrial district, but workers were drawn from the surrounding districts, transport being provided by means of trains and motor charabancs. A small township of about 160 houses was built close to the factory at Mancot to accommodate such staff and workers as it was essential to have close at hand. A small hospital for factory patients was included in this township. The Mancot township was erected by the Explosives Department

after an unsuccessful attempt to arrange a scheme with the Rural District Council. It was administered by the factory authorities. Female labour was employed from the very early days, women process workers being engaged in December, 1915. At first some doubt was felt as to the uses to which women could be put in an explosives factory, but ultimately about 70 per cent. of the workers on the chemical processes were women. At the period of maximum output the total number of factory employees was 7,325. In October, 1918, there were 3,749 workpeople, of whom 42·2 per cent. were women.

The total capital expenditure upon the two factories, viz., Queen's Ferry and Sandycroft, down to 31 March, 1918, was £4,046,300.

H.M. Factory, Rainham.[1]

The Rainham Chemical Works, situated on an island wharf on the bank of the Thames opposite to Woolwich, were taken over from the Synthetic Products Company by the War Department under the Defence of the Realm Act, on 28 November, 1914, the day after the Act became law. The situation of the factory subsequently rendered the work liable to interruption from air raids and warnings. Messrs. Coley and Wilbraham, who had installed the existing plant for the manufacture of butyl alcohol, were put in control of the factory and took up immediate occupation, under an agency agreement terminable at one month's notice. They were to convert the plant at state cost into a factory for purifying crude T.N.T., to be provided by the Department, at a fixed price of £5 per ton, and at the rate of 12 to 25 tons weekly as required. The conversion of the plant, which already included large enamel tanks then unobtainable in England, began on 3 December, 1914; the unit for crystallization was completed on 21 December and the first consignment of crude T.N.T. was received on 30 December. Previous to this the alcohol recovering tower was blown down in a gale.

The factory was first planned for the crystallization of T.N.T. from hot alcohol, but experiments with cold alcohol washing were initiated in January, 1915. Output from this process was unsatisfactory, as in addition to serious loss of alcohol, which the firm attributed to the rapidity with which the plant had been adapted, it caused corrosion in the stills. The output from the plant was far below expectation, being only 7 tons weekly, and the financial position of the agents was unsatisfactory. Accordingly in May, 1915, the administration was taken over by the Explosives Branch (then under the War Department) by agreement with the agents. Additional power plant, water supply and vacuum dryers for the recovery of alcohol, which had previously gone to waste, were installed between June and October, 1915, and further extensions including magazines, fire appliances, improved safety arrangements, and a new plant for the recovery of T.N.T. from waste amatol, were carried out between June, 1916, and May, 1917. By September, 1917, the average output of Grade I T.N.T.

[1] 74/C./39; 74/Fac./119; C.R. 2913; 31st Report of Standing Committee on Causes of Explosions.

was 60 tons per week, but owing to the demand for Grade II T.N.T. the greater part of the plant was given over to this product, and a considerable increase of output resulted.

On 13 February, 1918, a fire followed by explosion broke out in one of the vacuum stores for drying T.N.T. recovered from waste amatol, and the factory was almost completely destroyed. The fire service was under repair at the time, and the congested condition of the factory which had been built before T.N.T. was an explosive under the Act, added to the extent of the disaster, although the amount of T.N.T. present had been reduced to a minimum.

The employees in January, 1918, numbered 387. No women were employed.

The total expenditure on the factory shortly before its destruction was £35,000.

H.M. Factory, Sutton Oak (St. Helens).[1]

In February, 1915, the United Kingdom Chemical Products Company bought works, which were on the market, at Sutton Oak, near St. Helens, with a view to erecting plant there for the manufacture of synthetic phenol for the Government. The area of the land was a little over 16 acres. On 1 April, 1915, a contract was signed by which the Government undertook to pay the cost of installation of plant up to a specified maximum, to pay rent for the land during the currency of the agreement and to supply certain of the raw materials at agreed prices. The Government might, on further payment, instruct the company to double the plant capacity. The phenol supplied was to be at a fixed price. On 20 July, 1915, an additional contract was signed for benzol purification. The pure benzol produced was to be used for making the phenol under the previous contract. The method of manufacture was synthesis from benzene through benzene sulphonic acid and sodium salt.

There was considerable delay in the construction of the works. In October, 1915, a fresh agreement was signed cancelling the previous contracts. By it the factory became a government controlled factory, under the Explosives Supply Department. On 20 April, 1916, the United Kingdom Company was given notice terminating the contract, since the working and output of the factory were not considered satisfactory, and on 18 May, 1916, they were formally notified that possession of the works had been taken under the Defence of the Realm Act. Direct control of the works had actually been taken previous to this on 1 January, 1916, when the factory was put under the management of a superintendent appointed by the Department. Purchase of the company's shares was agreed upon in April, 1917.

The area of the buildings was 82,811 sq. ft. The original undertaking was to provide three tons of phenol a day—the company expecting to be able to produce one ton a day in two months' time and three tons a day a month later. In August 1915, the company was instructed to double the plant. Production began in November, 1915,

[1] Hist. Rec./H/1122.7/17.

the output at the end of that month being at the rate of one ton a day. In March, 1917, the output was 112 tons per month of 4 weeks, *i.e.*, an average of 4 tons a day. Between May, 1916, and 2 March, 1918, the total output was 1,700 tons. The production of phenol ceased in March, 1918, owing to the modification of the explosives programme, whereby picric acid lost its important position. The factory was, however, adapted for the production of some of the arsenic compounds required in 1918 for chemical warfare, chemical plant (autoclaves, etc.) being commandeered for the purpose. Chemical production began about November, 1918.

Owing to the nature of the work it was found necessary to make special holiday and sick pay arrangements for workers on chemicals. A fortnight's holiday was given after every six weeks of work in order to eliminate the arsenic from the system. The numbers employed in October, 1918, were 260, the percentage of women being 19·2.

The total estimated cost was £114,000. The actual expenditure down to 31 March, 1918, was £100,700.

H.M. Factory, Swindon (Stratton Works).[1]

At the close of 1916 it was proposed to take over land under the Defence of the Realm Act for the erection of a government ammonium nitrate factory at Swindon. The first land was taken in December, 1916, and more in February and May, 1917. The factory was erected on 67 acres, a mile and a half from Swindon Great Western Railway station. Construction began early in 1917, and output, with only a part of the plant completed, in September, 1917. In October, 1917, since output had been found to vary considerably according to temperature and the largest requirements were expected to be in the four hot months of the summer of 1918, it was decided to carry out extensions. The total area of the buildings erected was 340,087 ft. From the first, the factory was directly controlled by the Explosives Supply Department, being first under the Ammonium Nitrate Section, and later, from October, 1917, under the Factories Branch. It was managed by a superintendent. The "sulphate" process used was developed by Messrs. Brunner, Mond & Company.

The factory never had an opportunity to go "all out" but it could have produced 1,600 tons per week. As the continuous "sulphate" process used was a new one, and as the factory started up with only a part of the plant completed, production was at first restricted. Output was regulated in accordance with the ammonium nitrate requirements, and was limited during the greater part of 1918 to 500 tons per week. In September, 1918, instructions were given for a production of 1,000 tons per week, and when the Armistice was concluded preparations were being made for a production of 1,500 tons per week. The total output from start to finish was 25,050 tons. As regards cost of production, the "sulphate" process as used at Swindon proved considerably cheaper than the calcium nitrate process as used elsewhere, while it did not compare unfavourably with the ammonia soda process.

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[1] HIST. REC./H/1122.7/3; 74/Swindon/97, 135.

The whole of the labour for the factory, male and female, was drawn from the locality, with the exception of a few skilled workers. It was not necessary for the Government to provide either housing or transport for the workers, as accommodation was available in the town near by. The supply of labour was difficult in as much as the factory was among the last to start up, so that only low-grade and elderly men were available, while the female labour had to be drawn from domestic rather than industrial sources. In October, 1918, there were 1,246 employees, of whom 37·8 per cent. were women.

The total capital expenditure up to 31 March, 1919, amounted to £927,600.

H.M. Factory, Trafford Park (Manchester).[1]

A government refinery for the commercial toluol supplied by Messrs. Hardman and Holden, contractors, was built at Trafford Park, Barton, Manchester, on 8,400 sq. yds. of land. The Government held the land under agreement made with Trafford Park Estates, Ltd., with the option to purchase the freehold within 21 years. Contracts were drawn up with Messrs. Hardman and Holden both for erecting and working the factory. Construction began in October, 1915, and the factory was in working order in July, 1916. The area of the buildings was 17,216 sq. ft. The factory was operated by Messrs. Hardman and Holden, at a flat rate based on the output, a superintendent being in charge.

It was originally intended that the distillery should produce 20,000 gallons of pure toluol per week. By January, 1918, the output had reached considerably more than 40,000 gallons per week. The total production was 3,089,213 gallons of pure toluol and 315,400 gallons of solvent naphtha between the commencement and November, 1918, 457,608 gallons of pure benzol between the commencement and September, 1918, and 71,196 gallons of standard benzol between August, 1918, and November, 1918. There were very few employees, the number in October, 1918, being 27. Of these, 9 (33·3 per cent.) were women.

The estimated total capital expenditure was £33,383. The actual capital expenditure up to 31 March, 1919, was £37,400.

H.M. Factory, Victoria (Northwich).[2]

The site of H.M. Factory, Victoria, was about 50 acres of land situated 2½ miles from Northwich and 2 miles from Lostock, and with this latter place it was connected by the Trent and Mersey Canal. The original site was that of salt works belonging to the Salt Union, Ltd., and the land and existing buildings were rented from this company at a rent of £750 per annum for the duration of the war plus six months, at the end of which time the Ministry had an option to purchase the site, and the Salt Union, Ltd., to purchase the buildings erected by the Ministry. Additional land was taken under the Defence of the Realm Act and further buildings erected. The total area of the buildings was 461,802 sq. ft.

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[1] 74/T/1, 30, 44, 54, 78; 74/H/819. [2] HIST. REC./H/1122.7/5; 1520/14.

The factory was one of a group of units for ammonium nitrate manufacture in and about Northwich. The other members of the group began operation at various dates by diverse processes and were worked by contractors; Lostock and Sandbach by Messrs. Brunner, Mond, Plumbly by the Ammonia Soda Company, Fleetwood by the United Alkali Company. The Victoria Works were laid out for the production of calcium nitrate tetrahydrate in connection with the programme of January, 1916, for extending the production of ammonium nitrate. Throughout, Messrs. Brunner, Mond acted as technical advisers and general supervisors, but the Salt Union, Ltd., were responsible for the construction, operation and maintenance of the plant, acting as agents for the Minister until October, 1917, when the agreement with the company was terminated as this method of management had not worked smoothly. The factory was accordingly brought under the direct control of headquarters, being first under the Ammonium Nitrate Section and then under the Factories Branch.

By an agreement signed on 30 October, 1916, the Salt Union received 5 per cent. on the expenditure incurred on erecting and equipping the works, and a remuneration of 2s. 6d. per ton of calcium nitrate produced, with a guaranteed minimum of £2,000 and a maximum of £10,000 a year. Construction was begun in February to the designs of Messrs. Brunner, Mond, who acted as consulting engineers. Use was made of certain plant in existence at the Victoria Works and additional plant was brought in from other works; but it was necessary to reconstruct the whole of the buildings and to erect others. The factory was originally planned for a capacity of 1,500 tons per week, but in the autumn of 1916, extensions (originally intended to be a part of H.M. Factory, Albert) were made and these increased the weekly capacity by another 560 tons. Construction continued side by side with production till October, 1917. Output began in an experimental way in August, 1916; in November, 1916, it had reached 150 tons per week, and in November, 1917, it was 1,700 tons per week. A maximum output of 2,300 tons per week was reached in February, 1918, and the total calcium nitrate tetrahydrate produced exceeded 120,000 tons. The process was based on the reaction between calcium chloride and sodium nitrate, calcium nitrate and sodium chloride being formed. The calcium chloride, a by-product in the manufacture of bicarbonate of soda, was drawn from Lostock. The calcium nitrate tetrahydrate crystals produced at the Victoria Works were shipped by canal to Lostock for conversion into ammonium nitrate.

In October, 1916, sanction was given to a plan for erecting alongside the Victoria Works a second factory, the Albert Works, to make calcium chloride for conversion into ammonium nitrate at Fleetwood. Land was taken, but construction was restricted to the installation of 28 pans, which were connected up with the Victoria Works and operated as an extension of them. This change of plan took place towards the end of December, 1916, when a one-stage process for ammonium nitrate production had been worked out by Messrs. Brunner, Mond and decision taken to erect the Swindon Factory for manufacture by this method.[1]

[1] *See* above p. 77.

When work on the Victoria factory began, labour was exceedingly scarce as other large undertakings in the neighbourhood had absorbed many workers, and great difficulties were experienced in obtaining an adequate supply, recourse being had to military labour parties during the early part of 1917. At this time production was hampered by this lack of labour. Until May, 1917, only male labour was employed and it was not until the earlier constructional difficulties were overcome and production was reaching about 100 tons per day that female labour was employed. In October, 1917, at a time when the weekly output was 1,750 tons, the total number of employees was 2,423, of whom 41 per cent. were women. A year later the total number was 1,121, and the percentage of women 34·4. As housing accommodation was very limited, hostels to hold about 1,000 men were brought from Sheffield, where they had been found to exceed the needs of the locality[1]; and special trains were run to bring workers from neighbouring towns.

The total capital expenditure up to 31 March, 1919, was £608,300.

H.M. Factory, Watford.[2]

In the summer of 1915, the Explosives Department of the Ministry decided to supplement the supplies drawn from trade factories by erecting a State factory for the production of ammonal at the rate of 1,000 tons per month, primarily to supply the needs of the Russian Government and also to provide against the probable acceptance of this explosive in the future by the British services. The selection of a suitable site presented considerable difficulty, as it would be necessary to detonate sample charges at the factory at frequent intervals throughout the day, but in August, 1915, 61 acres of agricultural land two miles from Watford Junction were taken over under the Defence of the Realm Act, and the factory subsequently provided explosives for the Trench Warfare Filling Factories erected on the adjoining land.

On 19 July, 1915, the Department entered into two agreements for the erection, equipment and future operation of the ammonal factory. By one of these, Messrs. James Gordon & Company, a firm of engineers and contractors who had made special study of ammonal plant, were entrusted with the entire work of laying out and constructing the factory and supervising the erection of plant, for which they were to receive a commission of 6 per cent. on capital expenditure. The second agreement was made with Messrs. Roburite & Ammonal, the established makers of ammonal, and provided that, in consideration of a royalty of £1 per ton of ammonal produced, the firm should give full information and advice to assist in the construction, undertake the responsibility for the technical management and process of manufacture, maintain a regular inspection of operations and appoint the principal members of the staff, although the latter were directly controlled by, and responsible

[1] *See* Vol. V, Part V, p. 26 *n*.

[2] HIST. REC./R/1122.7/9; 74/H.E.A./39, 57, 58, 63; M.W. 103, 329. 74/Explosions/69 74/R/302.

to, the Department. All capital expenditure, salaries and working costs were borne by the State.

Construction began at the end of August. Alterations to the plans were made to enable the capacity to be doubled if necessary, but in spite of the changes work was carried on with such despatch that production became possible by December, although the necessary railway sidings were not completed, and additional buildings were added later. During the first weeks of production one incorporating house was brought into operation to produce 10 tons of ammonal daily, and it was also intended to manufacture bellite. The output rose slowly at first, some 2,727 tons of ammonal being delivered by May, 1916, and in June the output for the month was 867 tons, but the factory was also producing smoke powder and ophorite and carrying out experimental work. During the summer a large increase in production was effected and throughout the latter half of the year more than 3,000,000 tons were delivered. A fire occurred in February, 1917, in connection with the manufacture of a French incendiary composition, but the material damage done was not extensive.

Early in 1917 the use of ammonal was abandoned owing to the very great rise in the price of aluminium, and Watford with other factories previously making ammonal changed over to the production of amatol which became the standard high explosive for trench warfare purposes and aerial bombs.

Various methods of effecting the thorough mixing of T.N.T. and ammonium nitrate necessary for the production of amatol were in use by different factories. At Watford, liquid T.N.T. and solid ammonium nitrate were put, in the proportion of 20/80, into a Hind and Lund mixer which consisted of a cylindrical steam-heated box with a spiral stirrer. After being stirred the mixture was transferred to a cold mixer which turned out the amatol as a fine sandy powder. In 1917, the Watford factory was also temporarily engaged in re-treating stocks of sabulite for trench warfare use and in January, 1918, it undertook for a time the preparation of finely powdered T.N.T. for the special mixing plant at Chilwell Filling Factory. Throughout the summer the manufacture of amatol continued and in October the output reached 560 tons weekly of amatol and 88 tons of smoke powder, etc.

In order to secure the labour required for speedy construction workers were paid at London rates which were higher than those prevailing in the district, and little difficulty arose in drawing sufficient labourers. After production began the numbers employed varied between 200 and 400 and the proportion of women and boys ranged at different times from 19 to 28 per cent. of the whole. In October, 1918, the employees numbered 383, and 27·4 per cent. were women.

The estimates of capital expenditure presented in August, 1915, were £17,945 for buildings and £28,600 for plant. As much of the plant was of a new type and production of ammonal had not previously been carried out on so large a scale it was difficult to prepare estimates which were in any degree exact, while subsequent additions were made for new manufactures, *e.g.* ophorite, or proved necessary in view of practical difficulties. Thus the final cost was more than double the estimate,

and Messrs. Gordon's commission was therefore calculated only on the first £50,000. The actual capital expenditure to 31 March, 1919, amounted to £106,800

H.M. Factory, West Gorton (Manchester).[1]

Messrs. M. N. Morris & Company Ltd., of Gorton Brook, were one of the first manufacturers to put their resources at the disposal of the Government in the autumn of 1914. Their factory, which had been used for the production of aniline, was situated about two miles from the centre of Manchester on eight acres of land. It was in close proximity to Ashbury Station on the Great Central Railway, but had no siding into the works. The surroundings were densely populated, the district being for the most part laid out in small house property. Messrs. M. N. Morris & Company undertook to instal plant at their works for the production of synthetic phenol and M.N.T., the production of the former synthetically having been made necessary by the inadequacy of the supply of coal tar or natural phenol to meet the coming enormous expansion in the production of picric acid. On 6 January, 1915, a contract was made with the firm for 15 tons a week of phenol, and on 12 January for 3 tons a week of M.N.T. Owing to a change in the national programme of production the firm was asked later to turn over from M.N.T. to T.N.T.

Considerable difficulty was experienced with the phenol contract, for the synthetic process was a new one to England and had not been fully worked out here. The method of manufacture was synthesis from benzene through benzene sulphonic acid. There were special reasons connected with textile manufacture for working by way of magnesium benzene sulphonate, as the excess of acid remaining after sulphonation was recovered as Epsom Salt. The chemistry and technical conditions of manufacturing magnesium benzene sulphonate were worked out at Manchester University and a great deal of work in connection with the process was undertaken by the chemists of the South Metropolitan Gas Company. In June, 1915, a representative of the Explosives Supply Department was appointed to the factory to assist Mr. Morris and speed up construction work. The arrangements, however, did not work well. By the end of September, 1915, no phenol had been delivered and only one lot of T.N.T. (subsequently rejected), although by the contract output should have been reached long before that date. On 7 October, therefore, the works were taken over under the Defence of the Realm Act and West Gorton became a government factory.

In August, 1915, owing to the growing demands for picric acid, instructions had been given to double the phenol plant. The plant was finally designed to manufacture 40 tons of phenol per week of 7 days, although only 30 tons per week was guaranteed. The maximum output of phenol reached was an average of 21 tons a week during February, 1917, the total production between October, 1915, and July, 1917, when production ceased, being 1,225 tons. The steady capacity

[1] HIST. REC./H/1122.7/12.

of the T.N.T. plant was 80 tons per week. The maximum output of T.N.T. reached was 91 tons a week at the end of March, 1917, the total production between October, 1915, and 1917, being 2,900 tons.

Owing to the general arrangements and lay-out of the original factory, and the congested nature of the works, it was exceedingly difficult to render them suitable for producing what was required of them. Risks run in regard to fire and explosions were considerable, and owing to the disastrous effects likely to result from any mishaps of this nature in such a densely populated district, it was decided, early in 1917, to close down the benzol rectifying plant, and in June of the same year the T.N.T. plant was closed down. The manufacture of synthetic phenol by the magnesium process was throughout more or less of an experimental nature, and improvements and alterations in the process were continually being introduced. It proved expensive, and the sale of Epsom Salt produced could never have brought the magnesium process down in respect of cost to the level of the ordinary sodium salt process.

The total number employed in October, 1915, was 395 men. In June, 1916, this number had increased to 863. Labour was not difficult to get, but men were called away to the colours. The employment of female labour was begun in July, 1916. This proved satisfactory, and further female labour was utilized until a maximum of 240 women were employed in the week ending 20 March, 1917, the number of men employed at the same time being 640. In April, 1917, the maximum number of employees was reached, 992, of whom 24·1 per cent. were women. In October, 1918, there were only 72 employees, 5 of whom (6·9 per cent.) were women. Most of the employees were resident within walking distance of the factory, and for those living at a distance, trams and railways provided ample facilities.

The total capital expenditure down to 31 March, 1919, was £304,400.

III.—National Wood Distillation Factories and the King's Lynn Acetone Factory.

Wood Distillation Factories.[1]

In 1913, the Office of Woods and Forests had erected one small factory for wood-distillation at Coleford to utilize waste cord-wood from the Forest of Dean. Before the war this was the only wood-distillation factory in England, as it was thought impossible for British firms to compete with those in the great timber-growing countries of the world. Up to the end of 1915, therefore, practically the whole of the acetone required for British explosives, which was most easily obtained from grey acetate of lime produced from wood-distillation, was imported from America. At the time when the Ministry became responsible for supplies, the estimated service requirements were greatly

[1] 74/Factories/16; 95/3/3, 22; Hist. Rec./H/1530/1, 6, 9; Hist. Rec./R/400/5.

in excess of all the available American supplies, and efforts were made for the development of existing plant in England and the establishment of new factories. Thus, while the greater part of British requirements were still met in America, additional acetone was manufactured from acetate produced by various State wood-distillation factories established at home.

In 1915, new plant was set up at Coleford to produce 400 tons of acetone yearly upon the War Department's guarantee to take the whole output for the next ten years, at a price not exceeding £100 per ton. The Office of Woods was left to conclude its own arrangements for acetate, and erected two factories at Bideford and Dundee, where 1,200 tons of wood were carbonised weekly, producing, with the Coleford plant, most of the 2,000 tons necessary for the 400 tons of acetone. Messrs. Kynochs, Ltd., erected another wood-distillation factory at Longparish, in Hampshire where, after the summer of 1916, the firm produced part of the acetate required to manufacture the 42 tons of acetone which they contracted to deliver each month. In October, 1915, the Coleford factory, with Bideford and Dundee, was taken over entirely by the Ministry, and early in 1917 Kynochs' works also became a national factory.

In May, 1917, the Ministry instituted a centralised organisation for the sale of the by-products from these factories which had formerly been left to the discretion of the individual superintendents.

The plant in operation at Coleford was of German design, and the new factories were fitted up with American plant similar in principle. The capacity of the factories was between 400 and 500 tons of acetate per year, except at Bideford, which could produce 750 tons. The first output of acetone from Coleford was delivered in March, 1916, but during the summer the output was little more than half the estimated eight tons weekly.

In October, 1917, three new factories were planned for wood-distillation at Mid-Lavant (near Chichester), Ludlow and Carmarthen, to utilise the waste wood from felling operations carried on by the Timber Supply Department, and to provide from the by-products the necessary solvents required by aircraft manufacturers, whose demands were greatly increased at this time by the new aircraft programme. Construction of the first two factories began in the spring of 1918, but they had not reached the stage of production in November, 1918. They were completed for disposal, but as work was hardly begun at Carmarthen, the plans there were abandoned. In all the State wood-distillation factories acetate of lime was regarded as the main product, and in the largest factory the value of the by-products, chiefly charcoal, wood-tar and methyl-alcohol, more than covered the cost of the acetate. In the smaller factories, where service charges were proportionately higher, this result was not achieved, but production was carried on at a profit. The State intervention and control of processes resulted in the considerable development of modern scientific methods, while practically the whole production of the factories was used for war purposes. In the autumn of 1918 the employees at Bideford, Coleford, Dundee, and Longparish numbered 600, of whom 160 (27 per cent.)

were women. The capital expenditure on the first four factories, inclusive of Longparish, was £206,100, while an additional £171,100 was expended on the three later projects by March, 1919.

The following is a list of the factories :—

Factory.	Date of Starting or Nationalisation.
Wood Distillation—	
Bideford	1915
Dundee	1915
Longparish (Kynochs)	1917
Carmarthen	Construction began in 1918, but production was never reached.
Ludlow	
Mid-Lavant	
Wood Distillation and Acetone Production—	
Coleford (Forest of Dean)	1915

The King's Lynn Acetone Factory.[1]

Another method of acetone production had been in operation on a small scale before the war, at an oil-cake factory at King's Lynn, which had been converted by the Synthetic Products Company in 1912, for making acetone from the starch content of potatoes. In April, 1915, the company had undertaken to supply acetone at a price based upon the cost of potatoes. Advances were made towards extending the factory to produce seven tons a week, but the quality of the output was unsatisfactory. In view of this fact, and on account of the financial position of the company, the factory was taken over under the Defence of the Realm Act in March, 1916. Thenceforward it was directly controlled by the Propellants Branch of the Explosives Supply Department.

More satisfactory results were obtained by the Weizmann process for making acetone from maize, which was adopted in June, 1916. During the autumn of 1917, a collection of horse-chestnuts was organised throughout the country in order to provide a substitute for maize. Experimental work in producing acetone from chestnuts began at King's Lynn in April, 1918, but the poor quality of the material hampered output. The initial difficulties of manufacture from the new material had, however, been overcome when the factory was closed down in July, 1918. There were at that date 100 workers employed, 47 of whom were women. The capital expenditure on the factory by March, 1919, was £4,300.

IV. National Cotton-Waste Mills.[2]

In the late summer of 1915, when greatly increased quantities of cotton waste were required, by far the greater part of the supplies

[1] For acetone production in distilleries, *see* Vol. VII, Part IV, Chap. IV.

[2] HIST. REC./H/1530/1, 7, 10; 1500/5/4; 95/C/872, 889; HIST. REC./R/1122/10, 45; X/Labour/490.

of the country was controlled by the British and Foreign Supply Association. In September an assisted contract was placed with the Association to obtain 300 tons weekly for the national cordite factories from January, 1916, the Ministry bearing the cost of the additional mills and machinery required, but in August, 1917, this contract was superseded by an agreement under which the Ministry bought out the Association and acquired the mills, which the former directors continued to manage as agency factories. After some months, in order to give the mills the benefit of the technical and scientific knowledge of the Explosives Supply Department in the matter of the preparation and suitability of cotton waste for explosives, steps were taken to effect a closer control over the operations of the mills. The directors resigned and from May, 1918, each mill was regarded as a separate Government factory and directly controlled by the Propellants Branch. The factories were known as His Majesty's Cotton Waste Mills at Bury, Charlesworth, Greenfield, Hadfield, Oldham, Rawtenstall, Whaleybridge and Woodley. The former head office of the Association at Manchester was retained as the central administrative office for the mills, through which the Ministry exercised financial control and purchased raw material.

When the property of the Association was taken over in 1917, four mills were actually at work—Waterside Mill, Hadfield, which had been newly acquired in 1915 ; Holme Mill, Rawtenstall ; Calrows Mill, Bury, and Greenfield Mill. The mills at Charlesworth had been burnt down and were being rebuilt, and in April, 1918, Holts Mill at Oldham was also closed down. The Greenfield Mill was used in 1917 for experimental purposes in connection with the projected installations for nitro-cellulose powder production, and was closed down from August, 1917, to February, 1918, pending the results of manufacturing trials which were being carried out by Nobel's Explosives Company. In the spring of 1918 it was restaffed and equipped with new machinery at a cost of £1,200, and production began again on more scientific lines. The output was increased from an average of 41 tons weekly in April to 67 in October, and by the date of the Armistice had just reached 100 tons weekly. The quality of the cotton was also improved, and a reduction in cost of £22 per ton was effected in five months. By the end of the summer an additional 124 tons weekly of cotton waste was needed, and arrangements were made to reopen the mills at Whaleybridge on 30 September, and Cloughfold and Constablelee, Rawtenstall on 7 October. In November, 1918, all the mills were instructed to cease production.

The nationalisation of all the mills was followed, as in the case of Greenfield, by a general reorganisation, review of methods and increase of experimental work, which resulted in considerable improvements both in the quality and quantity of the output, while the efficient costing system introduced in several of the mills indicated that the financial results of the change were very satisfactory. The capital expenditure upon the mills down to 31 March, 1919, had amounted to £455,400.

CHAPTER III.

NATIONAL SHELL FACTORIES.

I. Introduction.[1]

(*a*) *The Origin of National Shell Factories.*

The National Shell Factory dates its existence from pre-Ministry days, and to Leeds belongs the honour of having provided the archetype.

In the spring of 1915, in response to the need for further methods for increasing munitions output, various local Munitions Committees had organised themselves throughout the country. They represented in the main the smaller engineering firms, many of whom had acted as sub-contractors to the armament firms, but were not themselves equipped for making complete shell. The earliest method of employing the resources of these committees was to form a co-operative group of firms, each of whom could undertake certain processes resulting ultimately in the assembling of the complete shell.

In April, 1915, it was arranged that the Leeds Munitions Committee (who had a co-operative scheme under consideration) should visit Woolwich to see processes.

> "They returned unanimously of the opinion that, in view of the difficulties as to machine tools, supervision, inspection and control the best method in a district was to select a suitable factory and concentrate tools, workmen, supervision, and inspection under one management on a non-profit basis, and while the factory was being equipped to send the management, together with selected skilled workmen to a properly organised ammunition factory for instruction."[2]

This idea of a national factory largely obviated the main weakness of a co-operative scheme, namely the difficulty of providing competent supervision and inspection on an adequate scale, and was accordingly approved by the Armaments Output Committee. On 7 May a draft scheme for the Leeds factory was approved in general outline, and the formal sanction of the Government to a revised form was obtained on the following day.

While the principle of co-operative groups was not abandoned, the establishment of a National Shell Factory was now offered as an alternative to Munitions Committees, to whom its concreteness

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[1] Vol. 1, Part III, Chap. IV; D.A.O./Misc./30, 238, 418, 1260; D.A.O./4/524; Hist. Rec./R/1121/46, 47, 48. *Factories and Products Lists.*

[2] Memorandum by Sir Percy Girouard, quoted in Vol. I, Part III, p. 71.

appealed, and by the close of June, 1915, some seventeen factories on the same lines as Leeds were already approved, while many others were projected.

(*b*) *Administration by Boards of Management.*

By the time the Ministry was established, a form of procedure had grown up with regard to local Munitions Committees which then became stereotyped. As soon as the proposals of any committee had been approved at headquarters they were instructed to submit from their numbers nominees for a Board of Management to carry out the proposed scheme. This Board, which was limited to about five persons[1] (generally engineers of standing), and only in one or two isolated cases included labour representatives, had to receive direct sanction from the Minister before it could embark on its work.

Once approved, the Board entered into an agreement with the Ministry, following in all cases the same model—that which was drawn up in May, 1915, between the Leeds Board of Management and the Government. The position of a Board of Management under its agreement may be thus summed up :—

(1) The Board was authorised to rent suitable premises at a rent approved by the Government, whose sanction was also to be obtained for the erection of any new buildings or extensions.

(2) The Board could equip the factory with machinery either by hire or purchase. Any purchase of new machinery was to be referred to the Government, who was to be the owner or lessor of all machinery in use at the factory.

(3) The Board was empowered to engage labour and appoint suitable engineering, administrative and secretarial staffs, and provide necessary staff accommodation. No salary in excess of £500 per annum was to be authorised without the prior approval of the Government.

(4) The Government was to place all necessary funds at the disposal of the Board, and an auditor to the factory was to be appointed by and responsible to the Government.[2]

(5) The Board offered their voluntary services to the Government, from whom they would receive technical advice and supervision. No member would receive any remuneration or profit in his individual capacity, but out-of-pocket expenses would be borne by the Government.

These early agreements gave the Boards of National Shell Factories very wide powers at a time when their local knowledge was of supreme importance, and when the headquarters staff was small in numbers and engaged in solving the problem of its own organisation. Later on, as the central organisation grew stronger, it was possible to exercise a greater control over the Boards, and their powers were to

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[1] For the *personnel* of the Boards, *see* Vol. II, Part II, App. IV.

[2] In April, 1917, the work of these auditors was brought into line with the work carried out by the headquarters audit staff at other national factories (D.A.O./Bds./65.)

a considerable extent restricted, though no clauses in the agreements were actually revoked.

Similar methods of management were adopted in the case of the National Filling Factories; but their Boards of Management did not report through the Director of Area Organisation.[1]

All necessary funds for administrative and working expenses were placed at the disposal of the Board. Administrative charges were automatically recovered by charging them to factory costs.

As administrative units the Boards of Management were attached to the department of the Ministry controlled by the Director of Area Organisation, to whom they were directly responsible, and who had ultimately the power to disband them. In order to co-ordinate this work with that of other departments of the Ministry, the D.A.O. Executive Committee was appointed in May and sat until December, 1916, to control all schemes administered by Boards of Management. It included representatives of the departments dealing with finance, supply, labour and contracts, and its functions were carried on in 1917 by the Shell and Components Manufacture Executive Committee, which, in addition to Board of Management schemes, included within its scope the management of National Projectile Factories, thus securing the closest co-operation on every side of a shell factory's work.

As regards the Area Offices set up throughout the country to represent the Ministry, the only officer with whom the management came into very close contact was the Superintending Engineer, for the National Shell Factory unlike the co-operative group was essentially a self-contained scheme. The practice established in July, 1915, of affiliating every National Shell Factory to a "mother" armament firm from whom technical assistance could be received fell, indeed, into abeyance with the appointment of Superintending Engineers, whose duties as technical advisers to all Boards of Management within their areas included the inspection of National Shell Factories, and investigations concerning and transference of available machinery.

For purposes of labour regulation and labour supply a National Shell Factory was classed as a controlled establishment.

(c) *Premises and Equipment.*

The selection of suitable factory premises formed a very important side of the self-imposed work of Boards of Management. Urgency was the essence of their early work, and, save in a few isolated instances (and those of a later date) existing premises were adapted to the purpose of shell-making, and in this way buildings of a totally unexpected character, as for example, an old herring-curing factory, a malt-house, toy factory, a roofed market, a rifle drill-hall, served their turn as National Shell Factories. Railway engine sheds and repairing shops were successfully adapted, and the corporations of various towns also placed premises in their Tramways or Electricity Departments at the disposal of the local Board.

In some instances engineering firms would offer shops in their own works, following in this the initial example of the Leeds Forge Company,

[1] *See* below, p. 149.

who furnished the first site for the Leeds national factories. In these cases the firm was represented on the Board of Management.[1]

In many cases premises were lent, rent free, for the duration of the war while in others a nominal rent only was taken.

The adaptation of premises not primarily intended for engineering purposes had drawbacks; owing to the construction of the buildings, the machines, which composed the plant, had to be laid close together; this congestion, together with low ceilings and narrow gangways, often made it difficult to fit up modern appliances, such as travelling or floor cranes.

A further handicap was often the machinery itself. The earliest efforts of the local committees had everywhere been to prepare some sort of census of surplus machinery in the district available for munition work which, in the case of a National Shell Factory, formed part of its preliminary equipment. Under their agreements with the Ministry, the Boards were empowered to hire or purchase this machinery. The general arrangement for hiring was that a Board paid 1½ per cent. per month on the agreed value of the machine (based on the original cost at the time of hiring)[2]. Some Boards, however, preferred to purchase second-hand machines and avoid later questions of depreciation.

The policy of the Boards was to instal plant as quickly as possible, but the most readily obtainable was not always the most suitable. Every Board was not so fortunate as Dundee, which secured the use of a prize cargo of American engine lathes intended for Germany, and there were many early complaints of hindrances caused by the break-down of second-hand machinery. The factory at Huddersfield, for instance, was seriously hindered at the outset by its local machinery, practically all of which had to be replaced before the end of 1915. At Bury, on the other hand, the lathes borrowed from various factories and mills in the neighbourhood, supplemented later by a few new Government machines, worked very successfully.

The local hire or purchase of second-hand machinery must be regarded as an early stage in the equipment of factories which, as they expanded their work, or it changed its character, received large additions of new machinery at the Ministry's expense; thus, the Haymarket National Shell Factory, at Liverpool, beginning with a "loan collection" of some sixty machines, had at the time of closing down 350. Some small factories, however, remained stationary; Portmadoc, for example, never exceeded an equipment of twenty-three lathes, of which four only were provided by the Ministry. While it would be both difficult and misleading to find figures to represent the percentage in National Shell Factories of second-hand and new equipment respectively, it is justifiable to state that but for this timely local help the larger factories would have had far greater difficulty in getting to work,[3] while the smaller factories could never have started at all.

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[1] In special cases premises were taken over piecemeal and administered by Boards (*see* Aberdeen, Ailsa Craig, College Park Works, Uskside).

[2] D.A.O./5/22.

[3] It should be noted that where new machinery was in question the National Shell Factories experienced all the delays in deliveries common to factories and contractors generally.

(*d*) *The Supply of Material.*

From the beginning the Ministry arranged directly for the supply of 18-pdr. shell steel to the National Shell Factories. As a general rule, forgings were also supplied in the same way, though in a few exceptional cases Boards were at first allowed to make their own arrangements. Early in 1916, the principle of central purchase of all forgings for National Shell Factories was fixed and was subsequently maintained, except as regards the Liverpool Board, one of whose factories produced the forgings required in their area.[1]

The supply of both shell steel and forgings to Boards of Management was to some extent secured and regulated by monthly allocations made in the Department of Area Organisation, based on reports from the Gun Ammunition Department. The allocation was sent to the Steel Department, which despatched issue warrants to the steel maker for approximately the amount allocated by the Department of Area Organisation, and, although the full quantity was seldom or never available, and deliveries were very irregular, the Boards in this way secured some proportion of their requirements during periods of shortage.

Shell components were at first purchased by the Boards themselves. The prices paid, however, differed so widely and had so much to do with the early high cost of shell, that at the beginning of 1916 a scheme was initiated for the central purchase of all component parts.

An interesting experiment was made by the Boards of National Shell Factories in the Lancashire area. Some time prior to June, 1918, they formed a committee for the co-operative purchase of all stores, which met at the Manchester Area Office, and kept in close touch with the departments dealing with purchases for National Projectile Factories.[2]

(*e*) *Work undertaken by the Factories.*

The exhibition of sample shells arranged in March, 1915, to be held at various centres for the information of intending contractors, had been confined to 18-pdr., 4·5-in., and 6-in. shell and No. 100 fuse; of these, the 4·5-in. and the 18-pdr. shell represented the most urgent need of the War Office at the moment. Mainly for this reason, but partly also because available machinery was best adapted for it, the greater number of National Shell Factories took up the manufacture either of 4·5-in. or 18-pdr. Hence, there arose in the early days of the Ministry, an artificial classification of national factories under which National Shell Factories were supposed to be limited to shell under 6-in., while 6-in. shell and upwards were the work of the National Projectile Factories. How arbitrary is this classification will be seen from the subjoined accounts of factories, for almost every type of shell up to 9·2-in. was subsequently produced in one or other of the National Shell Factories.

Various reasons make it impossible to estimate in round numbers the work of National Shell Factories as a whole. The hindrances likely to arise from unsuitable premises, or antiquated machinery, have been indicated, but there were other causes at work. In the first place,

[1] *See* below, p. 109. [2] (Printed) *Weekly Report* No. 147, VI A (22.6.18.)

when a Board of Management controlled both a National Shell Factory and a Co-operative Group, it was quite usual for the factory to undertake certain finishing processes for the group with a consequent diversion from its own output. One National Shell Factory indeed (Bristol), confined its work entirely to collecting, banding and varnishing shell produced by the West of England group of contractors. Again, National Shell Factories suffered very severely from the exigencies of the shell programme, and this more particularly in the case of the large number of factories manufacturing 18-pdr. shell, which, owing to the glut of that shell, were turned over in the summer of 1916, to other types of shell, only to be turned back again at the close of the year. Finally, the fact that not only were they national property, but that their administration was more directly under the immediate control of the Ministry than were other national factories, made it possible to turn them over on occasion to the supply of temporary needs, such as the manufacture of proof-shot of all types or the rectification of shell.

Some indication of the extent of the factories' contribution is, however, given by the following table, which shows the total deliveries into bond of the principal types of shell produced. In the majority of cases, the figures taken are those of shell actually manufactured in the factories, and do not include shell finished. The output of the Bristol factory is, however, included, and in some cases, such as Llanelly, rectified shell have also been counted. The output of the Leeds factories[1] is given with that of National Projectile Factories[2] and is not included here, while the figures for Ailsa Craig[3] are inclusive of deliveries after 1 June, 1918, when it became a National Projectile Factory. Details of the output of individual factories are given in Appendix I.

Nature of Shell.	Total Output, 1915.	Total Output, 1916.	Total Output, 1917.	Total Output, 1918.	Grand Total.
13-pdr. H.E.	9,400	324,300	57,100	10,600	401,400
18-pdr. H.E. Chemical and Smoke.	137,600	2,525,200	4,053,300	4,450,200	11,166,300
18-pdr. S.	—	—	—	167,200	167,200
2·75-in. H.E. ..	—	64,800	35,300	—	100,100
S. ..	—	1,300	3,000	—	4,300
3·7-in. H.E.	—	—	140,300	11,900	152,200
6-pdr. A.A.	—	19,100	2,100	—	21,200
4·5-in. H.E. and Chemical.	15,100	876,100	2,269,300	2,353,900	5,514,400
4·7-in. Chemical ..	—	—	3,400	—	3,400
60-pdr. H.E.	—	133,500	305,200	169,100	607,800
6-in. H.E.	1,000	195,500	716,100	812,600	1,725,200
8-in. H.E.	—	14,700	80,300	12,700	107,700
9·2-in. H.E.	—	—	29,400	25,900	55,300
Grand Total ..	163,100	4,154,500	7,694,800	8,014,100	20,026,500

[1] The total output of the Leeds group was :—144,000 4·5-in. ; 992,200 6-in. 13,800 8-in. ; 431,300 9·2-in. ; 6,600 12-in. ; and 7,300 15-in.

[2] *See* below p. 129.

[3] A total of 184,800 4·5-in. H.E.

It is claimed by the Director of Area Organisation that the National Shell Factories represented a great national saving, both directly by economic production, and indirectly by providing information from costings made in the factories which led to a general reduction in the price of shell to contractors. During the experimental stages, it is true, costs were necessarily high but, with one or two exceptions, they were reduced by June, 1916, to, or below, the level at which shell could be purchased from outside contractors.

Examples may be used to illustrate this point:—Liverpool claims to have saved in its four factories (manufacturing types of shell ranging from 18-pdr. to 8-in.) upwards of £841,000, on about £6,598,000, the latter sum representing standard prices of the Ministry. Bury, a small Board hampered by great difficulties, had by August, 1918, reduced the cost of 4·5-in. shell to 20s. 10·04d., considerably lower than the current contract price. Grimsby Board, also much handicapped by obsolete buildings, produced good results with 6-in. shell, bringing the cost in December, 1916, down to 61s. 5d., comparing favourably with the schedule price paid to contractors of £3 8s.

The total capital expenditure on National Shell Factories up to 31 March, 1918, amounted to approximately £2,523,000. This total includes expenditure on those factories which started as National Shell Factories but were later administered by other departments of the Ministry—*i.e.*, the Leeds factories, which became National Ordnance Factories and Ailsa Craig and College Park (Metropolitan Munitions Committee) which became National Projectile Factories. It also includes the Hartlepool factory, which was transferred to the Admiralty at the end of 1917. The figure for Leeds (£779,800) includes the cost of converting plant to gun work at Hunslet and Armley Road. In addition, the Rectification Factory at Bacup, which was not completed by March 1918, had a year later cost about £19,500.

In October, 1918 the employees in 40 factories numbered 18,375, the percentage of women being 6·5. The employees at the following factories are not included in these figures:—Hartlepool, Leeds, Ailsa Craig and College Park and Ebbw Vale (closed down). Labour conditions varied considerably owing to the diverse nature of the work undertaken and the differences in size between the factories. A note of the chief characteristics will be found under the account of each factory.

II. Individual Shell Factories.

The Barnsley National Shell Factories.[1]

No. 1 (*Dominion Works*).—In August, 1915, the Barnsley district, hitherto working in with Rotherham, set up an independent Board of Management, which, on 30 August, was formally authorised to establish a National Shell Factory. Premises were rented in the Dominion Works, Johnson Street, at a rent of £85, afterwards raised to £150.

[1] D.A.O./3/642, 646, 641, 717; HIST. REC./H/1121.23/2, 4.

An output of 500 4·5-in. shells, rising to at least 1,500 a week was offered. First deliveries were made in January, 1916. In 1917, when the factory was turned over to the production of 4·5-in. lachrymatory shell, the capacity was 4,000 a week. In January, 1918, it was decided to transfer the plant of this factory to the newly-established factory at Sackville Street.[1] The factory remained idle until September, 1918, when fresh 4·5-in. plant was installed, and at the time of the Armistice about one-third of it was in operation.[2]

A large number of local machines formed part of the original equipment, which was gradually replaced by new tools.

There was an ample supply of labour; in October, 1917, for example, it was reported that there were 400 names on the waiting list. In December, 1917, 446 people were employed, of whom 82·3 per cent. were women. The capital expenditure to 31 March, 1918, was £51,000.

No. 2. (Hope Works, Sackville Street).—In October, 1917, the Barnsley Board of Management offered to undertake a factory for the manufacture of 6-in. shell. The Ministry approved their scheme, which they estimated would take four months to get going. An old weaving shed and offices, known as the Hope Works, Sackville Street, were rented at £50 per annum, with an option of purchase subsequently exercised by the Ministry. Additional premises at £20 per annum were taken in June, 1918.

An output of 1,500 to 2,000 6-in. shells per week was promised, but before manufacture could begin, the scheme had to be abandoned owing to the steel shortage. It was then decided to transfer the 4·5-in. plant from No. 1 National Shell Factory to this factory, which was considered more convenient, and until the Armistice it produced an average of 4,000 shells a week. The total output from this and the No. 1 factory was 304,600. In March, 1918, the employees numbered 467, the percentage of women being 83·3.

The capital expenditure to 31 March, 1918, was £14,500.

Birmingham National Shell Factory.[3]

At the close of April, 1915, the Birmingham Munitions Committee on the recommendation of the War Office began to consider the possibility of establishing a National Shell Factory. Their original idea was to equip a factory for the finishing and assembling of contractors' shell only, but the plan developed and the agreement which was finally signed between the Ministry of Munitions and the Birmingham Board of Management on 14, June, 1915, authorised the Board to manufacture 4·5-in. shell on their own account, while also finishing shell obtained by co-operative methods.

The Board rented as a factory premises belonging to the Midland Railway Company Wagon Works at Washwood Heath and additional

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[1] *See* below No. 2 National Shell Factory.

[2] This factory after its fresh equipment is sometimes called No. 3 National Shell Factory, Barnsley.

[3] HIST. REC./H/1121.24/6; D.A.O./Misc/1394; D.A.O./4/1058; *Order and Supply Lists*; (Printed) *Weekly Reports, passim.*

premises were rented from January, 1916. A representative of the Company was appointed to the Board in February, 1916.

During the first year of its existence the control exercised by the Birmingham Board over the National Shell Factory was weak, owing partly to the fact that the offices of the Board were at the Council House, Birmingham, some distance away, and that the Board itself was mainly occupied with the work of the co-operative group. As a result, the factory delayed considerably in reaching the productive stage, and was unable to make adequate provision for the reception and inspection of contractors' work. Reforms were effected by the D.A.O. Executive Committee in June, 1916, when the administrative work of the Board was concentrated at the factory and a Secretary to the Board, who was also manager of the factory, was appointed.

The factory extended its original programme considerably, and the work which it undertook may be grouped as follows :—(*a*) The manufacture of 4·5-in. shell; (*b*) the finishing of contractors' shell; (*c*) the manufacture of 9·2-in. shell; (*d*) the manufacture of cartridge cases and copper bands; (*e*) the assembling of fuses; (*f*) the manufacture of gauges.

Under their original agreement the Board undertook to manufacture 5,000 4·5-in. shells a week. Delivery was delayed until February, 1916, but once started, output increased rapidly, and by August, 1916, had attained a maximum weekly output of 14,500 shells. In November, 1916, the Board was instructed to change over to 4·5-in. chemical shell, but in March, 1917, the instruction was cancelled before it had taken effect other than a disorganisation of the 4·5-in. shell shop.

The Board also originally agreed to finish in their factory at least 3,000 18-pdr. shells a week and an indefinite number of 4·5-in. produced by co-operative methods in the Birmingham District. In May, 1916, the manufacture of 18-pdr. shell was ordered to cease here as elsewhere, and on its general resumption in the autumn it was found that the 18-pdr. machinery in the Birmingham factory had been dispersed or absorbed in the manufacture of larger shell. The finishing of 4·5-in. shell continued throughout; before the close of 1915 contracts representing 10,000 4·5-in. shells a week were placed, and though this section of the factory's work did not get satisfactorily going till after the middle of 1916, a maximum capacity for finishing 12,000 shells a week was subsequently attained.

The total number of 18-pdr. shells manufactured by the factory to the end of 1918 was 57,000, and of 4·5-in. 1,736,300.

Towards the close of 1915, preparations were begun to equip a shop in the factory for the production of 9·2-in. There was considerable delay in installing machinery and shell was not delivered till October, 1916. In 1917 an output of 500 shells a week was attained, increasing in 1918 to 750. The total number manufactured was 49,200. In July, 1918, it was decided to stop production and in November, 1918, preparations were being made to hand the shop back to the company.

In July, 1915, plant was purchased for a cartridge case shop to produce 5,000 4·5-in. cases a week. It was allowed to be idle till well into

1916, when experimental work was begun, but by the beginning of July, only 50 cases were actually completed for inspection. It was then decided that as the supply of cases from other sources was adequate, while there was a greater scarcity of copper bands, the shop should be turned over to the production of the latter component. Owing to the delay in procuring the necessary equipment, 8-in., 6-in., 4·5-in. and 3-in. cartridge cases continued to be manufactured till November, 1916, by which date large numbers of copper bands were being turned out. This department henceforward supplied copper bands sufficient not only for the factory but for the whole district administered by the Birmingham Munitions Committee.

No manufacture of fuses was done in the factory, but a shop was equipped solely for the assembly and rectification of fuses and parts made by contractors to the Board. These operations were taken up early, and already in August, 1915, the Board reported to Mr. Lloyd George that contracts were placed for 5,000 fuses a week, augmented in November to 20,000. The Fuse Gallery was not fully organised till December, 1915, and there was at first a good deal of confusion owing to arrears to be dealt with. The Board also assembled primers, whose parts were severally contracted for by local firms.

The pressing need for gauges determined the Board early in November, 1915, to institute a gauge department of its own. The shop was equipped and in working order by January, 1916, and in April attained an output of 150 gauges of various calibres a week. In process of time this gauge department supplied the requirements of the factory and the co-operative group and also, at need, provided gauges for the Ministry, attaining an output of 400 gauges a week.

The maximum number of employees at the National Shell Factory (in November, 1917) was 2,400, of whom approximately 66 per cent. were women. By October, 1918, the numbers had fallen to 1,774, the percentage of women being then 62·5. There was no systematic Sunday labour but, especially in the early days of 1915–16, a considerable amount of work was performed by volunteers working as labourers and taking pay at ordinary piece-work rates.

The capital expenditure to 31 March, 1918, was £187,600.

Bradford National Shell Factory.[1]

The Bradford Munitions Committee, formed in April, 1915, decided that a factory on the same lines as that established at Leeds was their best method of employing local resources. On 19 May they made an offer to the War Office, and on 31 May were officially authorised to proceed with the scheme.

Part of the Valley Dyeworks Shed was taken on 26 June, 1915, at a rent of £600. On 3 April, 1916, a four-storey building belonging to the same works was sub-let by the Bradford Corporation to the Bradford Board of Management for £519 5*s*. A final addition, part also of the same works, was made to the factory in December, 1916, at a rent of £54 yearly.

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[1] D.A.O./3/518, 684, 246.

The Board undertook in its original agreement to produce 2,000 4·5-in. shells weekly. The first lot was bonded in November, 1915, and the factory's total output of finished shell to the end of 1918 was 654,000 4·5-in. H.E. and 23,800 4·5-in. chemical shells, as well as 125,000 bodies of 4·5-in. chemical shell, which were completed by the trade. In addition the Board manufactured 2,734,850 fuses, 1,921,400 gaines and 582,000 adapters. In the manufacture of the fuse the factory co-operated with contractors to the Board, who made a certain number of individual parts.

The early equipment was composed of some 814 lathes lent locally, such new machinery as was indispensable being made in the Bradford district. Its second-hand machinery had to be replaced subsequently by stronger and more suitable plant. In October, 1918, there were 738 employees in the shell department, of whom 74·7 were women and 244 (81·6 per cent. women) in the fuse department.

The capital expenditure to 31 March, 1918, was £56,700.

Bristol National Shell Factory.[1]

On 12 June, 1915, Mr. Lloyd George visited Bristol. He then strongly advocated the establishment of a National Shell Factory in addition to a co-operative scheme. The suggestion was acted on, and on 23 June the West of England Board of Management was authorised by the Army Council to establish a factory.[2]

Premises which would be central for the large and scattered area administered by the Committee had to be found. Works at Bristol, Swindon and Gloucester were examined, and the Castle Ironworks belonging to Messrs. J. Priest and Son, St. Philip's Marsh, Bristol, were eventually rented for £360 per annum.

Conditions in the area were more favourable to co-operative work, and it was decided to use the factory at first as an assembling place for co-operative shell and develop the manufacturing side later. Tools were collected for the latter purpose, but by the beginning of 1916 it became clear that there was little prospect of turning out complete shell, and the factory concentrated wholly on the completion of co-operative shell. The total output of finished shell delivered to bond was 3,033,200 18-pdr. H.E. and 167,200 rectified 18-pdr. shrapnel. The labour employed in October, 1918, numbered 348, the percentage of women being 86·5.

The capital expenditure to 31 March, 1918, was £20,000.

Bury National Shell Factory.[3]

Between June and August, 1915, the Bury Munitions Committee were considering the possibilities of establishing a national factory. A preliminary scheme for the production of 2,000 6-in. shells a week was submitted in August, but the suggested premises were not

[1] HIST. REC./H/1121.26/1 ; D.A.O./Misc./1394 ; HIST. REC./H/1121/5.
[2] Through an oversight ministerial approval was not received till 9 August.
[3] HIST. REC./H/1121.22/8 ; D.A.O./Misc./1394 ; Vol. II, Part II.

considered suitable by the Ministry and the scheme was rejected. In September the offer by the Bury Corporation of a part of their Central Tramway Depot rent free made it possible for Bury to make further proposals, and on 25 September the Ministry entered into an agreement with the Bury Board of Management.

Under this agreement the factory was to produce a small weekly output of 4·5-in. shell working up as quickly as possible to 1,000 weekly. The equipment consisted of ordinary engineering lathes, borrowed from the local mills and factories and fitted with the special equipment necessary for the manufacture of 4·5-in. shell bodies, supplemented by various special tools.

The factory turned out in all 111,900 4·5-in. H.E. shells and 31,500 18-pdr. smoke shell, and in addition undertook the rectification of proof and other shell.

As the factory occupied a central position no difficulty was found in maintaining a good supply of female labour, recruited mainly from the cotton and woollen mills in the neighbourhood, and dilution was maintained on the required scale. In October, 1918, women represented 79·3 of the total number (121).

The capital expenditure involved in the establishment and maintenance of this factory to 31 March, 1918, was £11,700.

Derby National Shell Factory.[1]

On 28 May, 1915, the War Office received a deputation of the Derby Munitions Committee, who came prepared with plans for a National Shell Factory. Consent was given to the scheme, and the committee instructed to appoint a Board which received approval on 15 June.

The site chosen was the Peel Foundry, in Darwen Terrace, a new building belonging to Messrs. Russell and Sons, from whom it was rented at £400 per annum. An additional shed was taken as a bonding store for £15 per annum. The building had to be adapted, and a railway siding was added in 1916.

The factory was controlled by a general manager, who was also Secretary to the Board. It was originally intended to supply 5,000 18-pdr. shells a week, but the Board was almost immediately instructed to make 4·5-in. shell, aiming at a weekly output of 4,000. First deliveries were made in December, 1915, and by August, 1916, a steady output of 6,000 was attained. In April, 1916, they were instructed to make 1,500 4·7-in. lachrymatory shells per week. During the steel shortage the factory employed slack time in machining 6-in. shell heads. With the spring of 1917 production of 4·5-in. shell mounted steadily, attaining a maximum of 9,000 in October. In January, 1918, the factory was turned over to the manufacture of aeroplane engine cylinders for the Rolls Royce Company, whose works for assembling engines were in the immediate neighbourhood, and manufacture of

[1] D.A.O./Misc/1394 ; D.A.O./4/959 ; Hist. Rec./H/1121.24/9.

shell gradually decreased, finally stopping in September. The total output of the factory to the end of 1918 was 546,300 4·5-in., and 3,400 4·7-in. shells, 60,400 6-in. shell heads, 4,100 60-pdr. heads, and 28,500 aero engine cylinders.

In the beginning a large proportion of plant was second-hand, but this was gradually replaced and supplemented by new machines. In 1918 these were removed and a complete acetylene welding plant and oxygen generating plant substituted for the work then undertaken on Rolls-Royce engines.

From September, 1915, women were employed, and this factory was the first where they were employed on a large scale on heavy shell. Of the 1,109 workpeople employed at the end of 1917, 75·6 per cent. were women. In October, 1918, the percentage of women was 50·5, the total number employed being 537.

The average cost of 4·5-in. shell worked out at £1 5s. 6d., and the lowest figure reached was £1 1s. 1½d. In May, 1916, the Board was informed that its costs were the lowest attained.

The capital expenditure to 31 March, 1918, was £75,000.

The East Cumberland National Shell Factory (Carlisle).[1]

Difficulties of organisation, including an unsuccessful attempt to collaborate with the western side of the county, delayed the intention of the local Munitions Committee for East Cumberland to set up a factory, and it was not until 14 August, 1915, that the Ministry approved a Board of Management for the purpose.

Arrangements to take over empty engineering works in Carlisle having fallen through, the Board approached the War Office with a view to acquiring the Rifle Drill Hall, which was placed at their disposition on 18 September, free of rent for the duration of the war; the Territorial Force Association also lent their hall, which was used for stores until 1918, when it was required for its original purpose. A neighbouring dwelling house was also taken over, and a mission hall was adapted for a canteen.

The factory was administered by the Board, acting in close co-operation with the Munitions Committee and with the Area Engineer. In their agreement with the Ministry, signed on 9 October, 1915, the Board undertook an initial weekly output of 1,500 18-pdr. shells, rising as quickly as possible to 2,000. They quickly exceeded this estimate, and in 1917 were producing 4,000 shells. The total number delivered was 304,600 18-pdr. H.E. and 2,000 18-pdr. smoke. In addition they stripped, cleaned and re-made for the artillery large quantities of proof-shot.

In October, 1918, the employees numbered 257, of whom 81·3 per cent. were women.

The capital expenditure to 31 March, 1918, was £12,800.

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[1] HIST. REC./H/1121.22/2; D.A.O./Misc./1394; HIST. REC./R/1121/29.

Grimsby National Shell Factory.[1]

Before July, 1915, a group of Grimsby engineers concerned themselves in making plans for a National Shell Factory, and even went so far as to purchase lathes for the purpose on their own initiative. At the beginning of August their scheme was brought into line with others, a local Munitions Committee was formed, and finally, on 19 August, a Board of Management was authorised by the Ministry.

The factory in Victoria Street, Grimsby, which the Board was empowered to lease at a rental of £535 per annum, was an old two-storied building formerly used as a herring-curing factory. Extensive alterations were made, but in spite of these the buildings remained in many ways inconvenient and the lay-out congested.

The Board undertook to begin with an output of from 250 to 1,000 6-in. H.E. shells a week, working up to a larger number if required. On 4 December, 1915, the first 250 shells were delivered into bond, and output steadily rose to over 3,000 shells a week in 1917. A small quantity of 4·5-in. were produced at the end of 1918, the total number produced up to the end of 1918 being 318,300 6-in. and 16,500 4·5-in. H.E. The early costs were extremely creditable, working out in January, 1916, at 68s. 10d., and in December, 1916, at 56s. 5d. per shell. The prices paid to contractors at these dates were £4 10s. and £3 8s. respectively.

It was not definitely settled until June, 1916, to employ women in the factory. The heavy nature of the shell and the inconvenient lay-out militated against the free exercise of dilution, and it was not until June, 1917, that the Board were able to introduce the required 80 per cent. of female labour. In September, 1918, the total number employed was 534, and the percentage of women was 78·1.

The capital expenditure to 31 March, 1918, was £28,700.

Hartlepool National Shell Factory (Tyne and Wear).[2]

The establishment of a National Shell Factory was discussed by the Tyne and Wear Board of Management as early as September, 1915. At the beginning of November the Board laid a definite scheme before the Ministry, under which they proposed to lease certain new boiler shops belonging to the Central Marine Engine Works, West Hartlepool, at a rental of £3,500. The proposed factory was to be managed by the Central Marine Engine Works for a sum of £2,500 per annum, plus 1s. per shell completed in the factory. The estimate for management was considered too high, and was eventually reduced to £2,000, plus 1s., and it was also laid down that all proposals for capital expenditure must first be submitted to the Ministry. Additional clauses enabling the Board to run a factory were added in their original agreement with the Ministry on 22 December, 1915, and a legal agreement was drawn up between the Board and the company.

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[1] HIST. REC./H/1121.21/3.

[2] HIST. REC./H/1121.21/4; D.A.O./Misc./1394; (Printed) *Weekly Report passim.*

The factory was designed to produce 1,400 8-in. shells a week. In October, 1917, when an output of 1,500 was reached, it was proposed to turn over to 6-in. shell, when a request was made by the Admiralty that the factory should be handed over to them as a boiler shop. It was decided to comply, and in December, 1917, production was ordered to cease. The total output was then 81,100 shells. In November, 1917, 435 workpeople were employed, and in spite of the heavy nature of the shell, 81·6 per cent. were women, who were recruited locally.

The capital expenditure to 31 March, 1918, was £45,800.

Huddersfield National Shell Factory.[1]

On 14 May, 1915, a local Munitions Committee formed in the preceding month at Huddersfield made an offer to the War Office to use their spare machinery to manufacture shell, preferably 18-pdrs. They were given the choice of forming a co-operative group or running a National Shell Factory, and they chose the latter alternative. On 2 June a Board of Management was authorised to carry out this scheme.

A three-storeyed building, in Fitzwilliam Street, and stores at the corner of Viaduct Street and Green Street, were taken at a rental of £300. The Secretary of the Board of Management acted as general manager of the factory throughout.

Under the Board's agreement, the factory was to begin with an output of 2,000 18-pdr. shells a week. In spite of various delays production began in November, and by the middle of 1916 was between 4,000 and 5,000 a week. The factory then turned over to shell heads, reverting to 18-pdr. shell in the spring of 1917. In May, 1917, the output was 5,000, and ultimately rose to 7,500. About 470,100 shells in all were manufactured.

The original equipment of the factory was 100 machine tools, hired or purchased in the district. These proved unsatisfactory, and had practically all been replaced by the end of 1915.

Labour conditions were satisfactory. Women were employed from the beginning, and in December, 1915, numbered 250, as compared with 102 men. In October, 1918, women labour accounted for 83·6 per cent. of the total number (329).

The capital expenditure to 31 March, 1918, was £31,500.

The Irish National Factories.[2]

Dublin 18-*Pounder Shell Factory.*—On 22 June, 1915, a deputation of the Dublin Munitions Committee made a definite proposal to the Director of Area Organisation to establish a National Shell Factory for 18-pdr. shell at Dublin, which was accepted. Suitable plant was earmarked, but some delay occurred before premises were decided on. These were a margarine factory belonging to the Great Southern and

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[1] HIST. REC./H/1121.23/1 ; D.A.O./Misc./1394.

[2] D.A.O./Ireland/505, 123, 68, 111 ; D.A.O. Unregistered papers (Ireland) ; D.A.O./Misc./1394 ; Vol. II, Part II.

Western Railway Company ; the situation was on the north bank of the Liffey about three miles from the Port of Dublin, and ample horse and motor haulage was available.

The adaptation of the building included the provision of shafting and fresh girder work.

The factory was at first under the immediate control of the Director of Munitions for Ireland, the factory manager, secretary and accountant being independent of each other and reporting separately to the Director. This did not prove very satisfactory and on the appointment of a new Board of Directors in September, 1917, a manager responsible only to them was appointed with full control over the entire factory.

Possession of the premises was not obtained until November, 1915, and production began in March, 1916. The output originally promised was 9,000 a week, but the total number of 18-pdr. H.E. and smoke-shell delivered into bond was 537,700, representing an average of about 4,000 shells weekly.

There was an amply supply of female and unskilled male labour in Dublin, though the girls, who were unaccustomed to the type of work, had to be trained. Skilled labour was scarce. In October, 1918, the total numbers employed in this, the 9·2-in. and the fuse factory, were 850, of whom 543 (63·9 per cent.) were women.

In June, 1918, a strike of the engineers employed in the factory took place and lasted three weeks. The workmen were warned that their action was an offence under the Munitions of War Act and thirty concerned were summoned before the munitions tribunal at Dublin and fined £3 each.[1]

Dublin 9·2-in. Shell Factory.—In March, 1916, the Ministry decided to establish a factory for 9·2-in. shell in Dublin on the same premises as the 18-pdr. factory, adequate accommodation being available. It was placed under the same management as the 18-pdr. factory.

The scheme was greatly delayed by failure to deliver plant and equipment and the first lot of shell was not bonded till April, 1917. An output of 500 shells a week was originally proposed, but the total deliveries were only 6,100 shell, and the proposed rate was never reached.

Dublin Fuse Factory.—The setting up of a fuse factory in Dublin had been for some time under consideration by the Ministry, before it was approved in May, 1916. This factory also was in the same grounds as the other Dublin factories, a new timber building with concrete foundations being built for the purpose.

The factory was at first regarded as part of the shell factory and was under the same management, but in September, 1917, was separated and henceforward had its own manager and system of accounts.

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[1] D.A.O./Misc./1394. Shortly afterwards four carpenters at Waterford Factory went on strike and under similar conditions were brought before the local tribunal and fined £10 each. It is understood that these two cases were the only instances in the United Kingdom in which the Ministry prosecuted members of trade unions for an illegal strike.

The output originally arranged for was 5,000 a week of fuse No. 101 in brass, and this was extended to 10,000 per week. The first delivery of these fuses was in March, 1917. The factory subsequently turned over to a new type, No. 103, of cast iron fuse with an output of 20,000 a week. A further change to No. 106 brass fuse was made later, with an output designed to reach 30,000. The total number of all types of fuses delivered was nearly 300,000.

This factory in addition undertook, in June, 1918, to manufacture aeroplane bolts and had delivered 193,160 at the time of the Armistice.

The capital expenditure on the three Dublin factories up to March, 1918, was £119,600.

Cork.—In 1915 the Cork Munitions Committee advocated the setting up of a national factory in the town, and in August were allotted plant for an 18-pdr. factory by the Ministry. This plant was subsequently diverted to Dublin and nothing further was done until the beginning of 1916, when Cork pressed its claims through the medium of the All Ireland Munitions Committee. The Ministry then approved a scheme for the manufacture of 4·5-in. shell and assigned the necessary plant.

The site chosen was a building, formerly used as a market, and known as St. Peter's Market, belonging to the Corporation of Cork, from whom it was rented. Railway facilities with Dublin were ample and there was a good shipping service from Cork to England.

The administration of this factory (as also of Waterford and Galway) followed the same lines as that of the Dublin Shell Factory.[1] Until 1917 the latter was considered the parent factory, and in certain cases workers were trained for the provincial factories, and tools supplied from the central tool room in Dublin. The employees at the Cork factory in October, 1918, numbered 147, of whom 112 (76·2 per cent.) were women.

There was considerable delay in equipping the factory, and the first delivery of 250 shell into bond did not take place till February, 1917. The total delivery of shell was 32,200.

The capital expenditure to March, 1918, was £14,000.

Waterford.—In the beginning of 1916, the All Ireland Munitions Committee clamoured for a National Shell Factory to be set up at Waterford, but it was not until the autumn that the Ministry decided to set up a factory for cartridge cases there.

A site, consisting of a disused railway siding, was taken over from the Great Southern and Western Railway, in November, 1916, under an Army Council Instruction, dated 19 November. An old engine shed was roofed in as a store and the Ministry constructed the main factory (a timber framed building with concrete floors), a power-house, cooling towers and the necessary offices. Both rail and water transport facilities were alongside the factory.

A plant designed to produce 20,000 cartridge cases per week was laid down. The first delivery into bond was made in August, 1917, and the total deliveries were 247,600.

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[1] *See* above p. 101.

In October, 1918, there were 529 employees, of whom 253 (47·8 per cent.) were women.

The capital expenditure to March, 1918, was £82,300.

Galway.—Towards the close of 1916, the Ministry consented to the establishment of a small 18-pdr. shell factory at Galway. A stone building, formerly used as marble and granite works, was adapted for the purpose and machinery sufficient to secure a weekly output of 500 shell was assigned. This machinery, which was second-hand, was received in January, 1917, when parts were found to be missing or badly damaged, leading to some delay.

There was practically no skilled labour available locally, and it was necessary to import mechanics to do the initial work and train such labour as could be obtained in Galway. The employees in the autumn of 1918 numbered 116, of whom 96 (82·7 per cent.) were women.

The total number of shells manufactured was 33,600.

The capital expenditure to March, 1918, was only £4,000.

Keighley National Shell Factories.[1]

No. 1 Dalton Lane.—On 31 May, 1915, the Army Council authorised the Keighley Board of Management to carry out a scheme for a National Shell Factory. Premises were rented for the purpose from Messrs. Prince, Smith & Sons, Keighley.

The Board of Management remained in very close touch with the administration of this factory, whose record was a particularly successful one.

The intended capacity was for 5,000 18-pdr., but by 1917 this output was more than doubled. In October, 1916, adjoining premises were taken, and plant for the production of 3·7-in. shell installed. The total output to the end of 1918 was 619,900 18-pdrs. (H.E. and Chemical), 152,200 3·7-in. and 21,200 6-pdr. anti-aircraft shell. The factory also turned out quantities of 6-in. shellheads.

The costs at this factory were very satisfactory, representing in 1917–18 a saving of £89,921 on the standard Ministry prices.

Female labour was freely used from the beginning, an average of 85 per cent. of women to 15 per cent. men being employed. The maximum numbers employed in the factory reached about 500 at the end of 1917. In October, 1918, of 417 workpeople, 83·7 per cent. were women.

The capital expenditure to 31 March, 1918, was £51,200.

No. 2 Dalton Lane.—In October, 1917, when the question of increasing the output of 6-in. shell was under ministerial discussion, the Keighley Board put forward a definite scheme for a factory which was formally authorised on 14 November, 1917.

A site, on which were the foundations of a foundry, was offered rent free by Messrs. Hall & Steels. On this the Ministry erected premises to be purchased by the firm at cost price less depreciation on the conclusion of the war.

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[1] D.A.O./3/743, 672, 641, 517; (Printed) *Weekly Report*, No. 160, VI (A.) (21.9.18).

An output of 3,000 or more shells was promised, but in January, 1918, when experimental work was in sight, the Ministry was compelled, by the shortage of steel, to order the abandonment of the scheme. A suggestion that the factory might manufacture aircraft parts was negatived, as the building proved unsuitable, and finally a scheme submitted by the Board in June, 1918, to produce either 4·5-in. or 18-pdr. castings was adopted in favour of the latter. In September, 1918, the factory was turning out 9,000 castings a week.

Leeds National Shell Factories.[1]

The conditions under which Leeds, the first of the National Shell Factories, came into being, have been indicated above.[2] Credit for the initiation of the scheme was largely due to the Leeds Forge Company, who furnished the first site and whose representatives were included on the Board of Management. Five national factories were eventually set up in Leeds to manufacture shell and components and were all administered locally by the Leeds Board of Management. With regard to their administration from head quarters, until the end of 1917 they belonged technically to the class of National Projectile Factories. They were, however, considered as Board of Management schemes and remained attached to the Department of Area Organisation until August, 1916, when they were transferred to the section dealing with National Projectile Factories. In 1917 one of the factories (Hunslet) turned over to the repair and manufacture of 18-pdr. guns, and in order to avoid dual control all the factories were transferred to the administration of the Gun Manufacture Department, and were known as the National Ordnance Factories, Leeds, from September, 1917. The local administration remained the same throughout the war, though in 1918 the Board of Management was known as the Board of Control.

Altogether, over 1½ million shell were produced by the Leeds factories, the output of the principal types to the end of 1918 being as follows: 4·5-in., 144,000; 6-in., 992,200; 8-in., 13,800; 9·2-in., 431,300; 12-in., 6,600; 15-in., 7,300. Large quantities of components were also produced and other work undertaken included the manufacture of 2-pdr. shell, 6-in. shrapnel shell, and mine sinker parts and the rectification of unfired shell and of shell recovered from the sea after proof at Shoeburyness.

The history of the individual factories was as follows:—

Armley Road.—This factory was the earliest to be established, the agreement between the Board of Management and the Ministry of Munitions being dated 20 May, 1915. New buildings intended for railway carriage shops were rented from the Leeds Forge Company, whose officials worked the factory under the general control of the Leeds Board of Management. Additional buildings were erected by the Ministry at a cost of £47,000.

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[1] 94/Leeds/5; 93/Nat./139; C.S.M. 20564; HIST. REC./R/1122.2/2, 1121.23/2, 11; (Printed) *Weekly Report, passim*; D.A.O./3/286, 358.

[2] *See* above, p.87.

The original offer of the Board was to manufacture 20,000 18-pdr. shell weekly, working up to 40,000, but they were almost immediately instructed to turn over to 4·5-in. shell and steps were also taken in July to equip a 6-in. shop. In spite of their willingness, local firms were only able to contribute about 40 lathes to the original equipment of 250, as their machines were not suited to the type of shell. The output of 4·5 in. was intended to be 5,000 a week, but this was considerably exceeded. Deliveries began in September, 1915, in November the promised rate was reached and by March, 1916, the weekly output was 10,000. Soon after this the plant was turned over to 6-in. on which the factory concentrated thenceforward. The original 6-in. shop was designed for 3,000, but in 1918 the total output averaged over 10,000 a week. The cost of the 6-in. shell was then £2 17s. 10d. and this represented a saving of £20,000 a month over the contract price of £3 6s. 10d.

A tool shop was established in connection with the factory. It supplied tools to all the Leeds factories and was extended in 1918 to include the manufacture of gauges.

After the factories were transferred to the Gun Manufacture Department the Armley Road Factory was known as National Ordnance Factory No. 3. A certain amount of rifling of guns was done here until the end of 1917, when the work was transferred to Hunslet. Gun inspection was also carried out, and in 1918 one of three additional bays taken over from the Leeds Forge Company was allocated to the Inspector of Guns for the before and after proof inspection of guns tested at the Meanwood Range, which was under the control of the Leeds Board of Management.

There was no early difficulty as to labour, and a contingent of 40 or 50 men was sent to Messrs. Armstrong's works at Newcastle to take three weeks instruction in shell and lathe work. In February, 1917, there were 1,471 men and 810 women employed in the factory and in October, 1918, the total number was 2,318, of whom 62 per cent. were women.

The capital expenditure on the factory to 31 March, 1918, amounted to £248,400.

Newlay.—Some time before 10 August, 1915, when Mr. Lloyd George interviewed the Leeds Board of Management, the Ministry had accepted their offer to erect a factory for the manufacture of 2,000 9·2-in. shell a week.

The site chosen was some seven miles from the Armley Factory, up the River Aire. The land was held under agreement with the Schoen Wheel Company, and all the buildings were erected by the Ministry, at a total cost of £78,000. The factory was controlled by the Leeds Forge Company.

First deliveries were promised by the close of March, 1916, but were delayed, the first shell being produced in April. At the beginning of 1917 an output of 2,750 shell per week was attained and during 1918 it averaged between 3 and 4,000. The factory was also equipped later for the production of 15-in. shell and in February, 1917, was turning out about 300 of this nature a week. The cost of producing 9·2-in. shell

at the beginning of 1917 was £8 15s. 11d., compared with the contract price of £10 17s. 6d. and of 15-in. shell £38 2s. 9d. as opposed to £40.

On the change of administration at the end of 1917, this factory became known as National Ordnance Factory No. 1.

At the beginning of 1917, the factory employed 1,307 men and 639 women. In October, 1918, the total number was 1,792 women, being 50·4 per cent. of the whole. The capital expenditure to 31 March, 1918, was £230,600.

Hunslet.—In 1916 the Leeds Board of Management established a further factory for the intended manufacture of 200 15-in. and 2,000 9·2-in. shell a week. Derelict premises at Goodman Street Works were taken over for the purpose under the Defence of the Realm Act, a rent of £582 per annum being paid for them.

The first 9·2-in. shell was produced at the end of August, 1916, and the first 15-in. a fortnight later, but the factory had hardly reached its maximum output early in 1917 when it was instructed to turn over to the relining and rifling of 18-pdr. guns.

Shell manufacture gradually ceased, though rectification of shell continued until the middle of 1918.

The first repaired gun was produced in August, 1917, and a few months later the manufacture of 18-pdr. guns Mark II began, the ultimate capacity being 150 repaired and 200 new guns a month. The factory, which was known as National Ordnance Factory, No. 2, undertook the 18-pdr. Mark IV gun in 1918, and other work done included the rifling of 60-pdr. guns and of 6-in., 8-in. and 9·2-in. howitzers and the manufacture of 18-pdr. recuperators and 6-in. and 8-in. recuperator liners. At the time of the Armistice a new carriage erection shop, to deal with 18-pdrs. Mark III, was in process of construction.

In February, 1917, before the change to gun work, the number of men employed in the factory was 1,563 and of women 960. The total numbers in October, 1918, were 1,750, of whom 397 (22·7 per cent.) were women. In March, 1918, output was delayed by a strike which began at Hunslet and spread to the other factories, involving practically all the workers and lasting for some days. The immediate cause was the dismissal of four men who had refused to carry out a foreman's orders, but there had been labour trouble for some time, particularly at Newlay, owing to a prospective alteration in bonus.

The total capital expenditure on the factory to March, 1918, including the cost of converting plant to gun work, was £274,400.

The Fuse Factory.—Early in 1916 the Leeds Board of Management took over a factory for the manufacture of the No. 106 fuse from the Leeds Munition Company and transferred the work to premises adjacent to the Armley Road Factory, which were part of the works of Messrs. Jonathan Hattersley & Sons, spindle manufacturers, and were rented from the firm. A gallery was added to the north side of the Leeds Forge Company's works, and this was at first used for assembling and gauging fuses and other components made by sub-contractors, but later this gallery was removed and the work was transferred to buildings rented for the purpose in Wellington Street and Sweet Street. In 1918 the

Armley Road Fuse Factory was known as National Ordnance Factory No. 4, Wellington Street as No. 5 and Sweet Street as No. 6. By the middle of 1918 the output of fuses from the three shops had reached 100,000 a week. The Armley Road Factory also made steel hammer castings, the output being about 40,000 a week and other components dealt with included primers, gaines, exploder containers, fuse hole plugs, etc., while primers and cartridge cases were also repaired.

In February, 1917, the labour employed on fuse work was 106 men and 774 women, while in October, 1918, of 1,470 employees 86·2 per cent. were women. The capital expenditure on the fuse department to 31 March, 1918, amounted to £26,400.

The Liverpool National Shell Factories.[1]

Haymarket.—In June, 1915, the Liverpool Committee decided to establish a national factory as part of their work. The Corporation offer, rent free, of part of a building used before the war as an agricultural produce market was accepted. The position was excellent, near the centre of the city and close to the docks and railway stations.

The management of the factory was under the control of the City Engineer, the Liverpool Board of Management maintaining a general supervision.

At the outset, the factory was organised to produce 18-pdr. shell. In June, 1916, it was instructed to turn over to machining 4·5-in. and 6-in. shell. The total number of shell manufactured by this and the other Liverpool factories was as follows:—1,873,900 18-pdr. (H.E. chemical and smoke), 46,100 2·75-in. H.E.; 6,600 60-pdr. H.E.; 797,300 4·5-in. H.E.; 431,900 6-in. H.E.; 26,600 8-in. H.E.

The original plant at the Haymarket factory, numbering about 60 machines, was lent by various Corporation Departments, Poor Law Institutions and other public bodies and by private firms. Additions were made from time to time, and when closed down there were about 350 lathes and other machines, and two acres, or half the total area of the market had been appropriated. The early plant was installed mainly with a view to quick delivery more than to economy of working but towards the end of its career the costs at this factory were becoming very satisfactory.

Labour was plentiful and the extent of female dilution was high, attaining to 83 per cent. of the total employed at the beginning of 1918. In October, 1918, of 1,603 employees, 79·6 per cent. were women.

The capital expenditure incurred was £131,000.

Cunard.—Towards the end of June, 1915, the Liverpool Committee entered into negotiations with the Cunard Steamship Company to establish a munitions factory. It was at first suggested that it should be run on non-profit-earning lines but the ordinary scheme of a National Shell Factory was almost immediately substituted.

The premises selected were a new warehouse for ships' fittings belonging to the company. The building was extended at the rear and

[1] HIST. REC./H/1121.22/1; HIST. REC./R/1121/29; D.A.O./Misc./1394.

an additional storey, with a concrete floor and steel girders, was added by the Ministry. The position, in a main thoroughfare and near the Gladstone Docks, was good.

The factory was under the direct supervision of the Cunard Company's Superintendent Engineer and was subject to the general control of the Liverpool Board of Management.

It was originally intended to manufacture 4·5-in. shell but Mr. (afterwards Sir Glynn) West, who visited the works in September, 1915, decided that part of the machinery should be turned over to 8-in. shell, and the manufacture of 6-in. was also taken up. The estimated output was 350 8-in., 2,000 6-in. and 2,500 4·5-in. shell a week.

Most of the machinery was of the type suitable to marine work and required to be specially adapted for shell. All tools and gauges were eventually made on the premises and also many of the spares so that the factory became practically self-contained.

Labour was plentiful throughout. The women, who in October, 1918, numbered 73·8 per cent. of the 1,110 employees, were of a superior class and speedily became proficient. They did their own gauging and in many instances their own tool-setting. All lathes were operated by women, and this factory had the distinction of producing the first 8-in. and 6-in. shell made by female labour.

The committee's proportion of the capital expenditure incurred was £16,600.

Edge Lane.—This factory was one of the early schemes of the Liverpool Munitions Committee. A steel frame structure, afterwards extended for stores, toolroom, etc., on the site of the Liverpool Exhibition of 1886 and subsequent years was chosen for premises, and was approved by Mr. West in September, 1915. The site was rented from the Liverpool Corporation at £900 per annum. The factory was designed to produce 4·5-in. and 6-in. shell forgings and also to manufacture cartridge cases. Owing to delays in the delivery of plant, the forging-factory did not produce until February, 1916, while there was even more serious delay on the cartridge case side, which did not receive its full equipment till August, 1916.

The factory was managed by a staff working under the general direction of the Liverpool Board. The inspection of forgings was carried out independently by the Liverpool Committee's technical superintendent.

The forging factory supplied the needs of the Liverpool Co-operative Group ; the greatest number of forgings made in one week was 28,000. The total output was 1,055,300 4·5-in. forgings and 757,400 6-in. The authorised output of 4·5-in. short howitzer cartridge cases was 20,000 a week, the number actually attained was 28,000 ; during 1917 and 1918 a total of 704,300 was delivered.

All employees had to be trained, as the industry was new to the district ; labour, both male and female, was abundant, except in the billet shops where the work was heavy and fit men scarce. The total number employed in October, 1918, was 757, 40·6 per cent. being women. The capital expenditure incurred was £96,000.

Lambeth Road.—In June 1915, the Liverpool Corporation offered to the Liverpool Munitions Committee part of the Lambeth Road Works of their Tramway Department to be used mainly as a depot for issuing material to and finishing the shell of their contractors. The offer was accepted and the factory was managed by the Manager of the Corporation Tramways acting under the general supervision of the Liverpool Board of Management. By the end of July 1916, it was in working order.

The main work of the factory was devoted to the finishing and rectifying of shell machined by the local contractors. In addition an output of 2,000 18-pdr. shells weekly was maintained. The capacity for finishing was originally estimated at 10,500 shells weekly but the actual numbers varied between 12,000 and 21,000. The total number of shell passed through the factory was 1,624,600 18-pdrs., 169,700 4·5-in., 40,600 2·75-in., 6,600 60-pdrs., 1,600 15-pdrs. and 17,100 18-pdr. smoke. In addition a large amount of material was distributed from the factory.

The lay-out was specially good. It was equipped originally with a large number of machines lent by the Corporation and private firms. These were subsequently reinforced by new tools purchased by the Ministry.

There was an abundance of female labour and a fair quantity of semi-skilled male labour available. Skilled labour was transferred from the Tramways Department as required. In October 1918, the total number employed was 363, of whom 86·5 per cent. were women.

The capital expenditure on this scheme was comparatively slight, being £22,000.

Bootle.—The difficulty of getting an adequate supply of satisfactory gauges led the Liverpool Board to consider the question of establishing a small gauge factory on national factory lines to cope with the demands of their district. On 2 November, 1915, ministerial approval was given to the scheme.

The premises of the Technical Engineering Company in Clyde Street, used for model and toy-making were taken over and additional accommodation provided by erecting a two storey building of wood and asbestos cement in the yard.

The plant consisted at first almost entirely of that taken over with the building, but was considerably augmented later. The factory turned out 20,000 gauges composed of over 1,500 distinct types and kinds.

There was not a large supply of skilled tool-makers, but women proved very adaptable to the work. Of the 52 employees in October 1918, 21 (40·4 per cent.) were women. The capital expenditure incurred was £6,300.

Chester.—In June 1915, the Corporation of Chester submitted a scheme for a National Shell Factory to the Liverpool Munitions Committee. The scheme was approved and submitted to the Ministry, receiving sanction in August 1915.

The boiler house of the electricity works of the city was placed at the disposal of the committee, rent free, by the Corporation. The administrative staff of the electricity works, acting under the general supervision of the Liverpool Board, managed the factory.

The original intention was to produce 15-pdrs., but in December, 1915, a change was ordered to 13-pdrs. and before this could be accomplished a further change to 2·75-in., which were manufactured till March 1917. A turn-over to 18-pdr. shell was then made. The estimated output was 1,000 a week, but owing to the frequent breakdown of plant, it was found difficult to keep up to 800 on two shifts; a day shift only was ultimately worked reducing output to 600 but with a corresponding reduction in working costs.

The equipment of the factory was very small, about 14 lathes and a few other machines, and was almost entirely second-hand, borrowed from various works and private owners. The factory only machined the shell, finishing operations being carried out at the Lambeth Road Factory.

An attempt was made to run the factory by local voluntary labour, but the results were not satisfactory. In September 1918, there were 37 employees, and of these 21 (56·7 per cent.) were women. The capital expenditure incurred was £2,400.

Manchester National Shell Factory.[1]

In October 1915, a scheme for a National Shell Factory was propounded by the Manchester Corporation Tramways Committee, who offered to set aside a portion of their Hyde Road Depot, rent free, for the purpose. After some delay spent in discussing preliminaries and settling the nature of the shell to be manufactured, the offer was accepted by the Ministry of Munitions early in 1916.

On 8 March, 1916, a Board of Management was authorised to administer the factory. It was entirely independent of the Manchester Board which already existed for a co-operative group, but included representatives of the latter among its members. A works manager was appointed to work under this Board.

The factory was equipped with machinery sufficient for an output of 2,000 4·5-in. shells weekly. It began with 500 a week and had attained the required number by 1917. Its total output by the end of 1918 was 88,900 shells.

The number of employees in October 1918 was 252, 79 per cent. being women. The capital expenditure to 31 March, 1918, was £16,500.

The Metropolitan Munitions Committee Factories.[2]

Ailsa Craig Works.—On 11 September, 1915, the Metropolitan Munitions Committee placed a contract with the Ailsa Craig Motor Company for 120,000 4·5-in. H.E. The contractors were to receive financial assistance towards building a new shop and installing the

[1] D.A.O./2/349; D.A.O./Misc./1394; HIST. REC./R/1121/29.
[2] HIST. REC./H/1121.27/1; (Printed) *Weekly Report, passim.*

necessary plant. At the beginning of 1916, the committee, while investigating the demands of the company for a further payment in advance, found preparations very behindhand, and on a far too elaborate scale. By the middle of April 1916, the new shop was still incomplete, while about 20,000 shells in various stages of machining were passing through the old shops. Acting in consultation with the Ministry the Metropolitan Munitions Committee decided in May 1916 to exercise their power under the Defence of the Realm Regulations to put in one of their officials to manage the works. Action was to be suspended for one month, when, if satisfactory progress were shown, it would be withheld. The company threatened to take legal action against the Metropolitan Munitions Committee, but conditions failing to improve, the Ministry persevered in its decision, and on 20 July, 1916, the Defence of the Realm Act was put into operation.

The works thus taken over were managed by the Metropolitan Munitions Committee, reporting to the Director of Area Organisation. Shell was henceforward produced at cost price, and the works classed as a National Shell Factory. On the dissolution of the Metropolitan Munitions Committee, in May, 1918, the factory came under the direct control of the Ministry, and in June, 1918, was placed under the administration of the Controller of Gun Ammunition, being classed as a National Projectile Factory.

The Ailsa Craig Works continued to manufacture 4·5 in. shell. In July, 1918, the output rose to over 2,000 shells a week, and in the following month varied between 3,000 and 4,000, attaining in September a maximum of 5,131. The total output to the end of 1918 was 253,200.

The numbers employed in March, 1918, were 608, of whom 54·9 per cent. were women. In February, 1919, the general manager brought forward an interesting suggestion as to the disposal of this factory, proposing to take it over and run it on a profit-sharing or co-operative basis. He was informed that a commercially sound scheme would be considered, and was allowed three months to complete his financial arrangement, and meanwhile given motor lorry repair work to keep the factory going. At the end of that time, however, negotiations were still pending, and it was decided to dispose of the factory in the ordinary way. The capital expenditure to 31 March, 1918, was £26,400.

College Park Works.—This small factory consisted of the works of Messrs. Klinger, alien enemies, manufacturers of engine packing, etc., and was taken over under the Defence of the Realm Regulations in October, 1915, by the Metropolitan Munitions Committee. Further tools were installed, and the shop was at first employed as accessory to the work of the Perivale Filling Factory, but later turned over to making shrapnel discs and sockets. It was classed as a National Shell Factory until the dissolution of the Metropolitan Munitions Committee, when it came directly under Ministry control, and was administered as a National Projectile Factory. There were only 122 employees in March, 1918, of whom 76 (62·3 per cent.) were women. The capital expenditure to 31 March, 1918, was £4,000.

The North Wales National Shell Factories.[1]

Wrexham.—In July, 1915, the Wrexham Munitions Committee presented a scheme for a National Shell Factory to the Liverpool Trustees, asking for affiliation with that body. The scheme was approved, and a grant made by the trustees to enable Wrexham to start work. Meanwhile, plans were being made to organise North Wales as a whole, and after some delay Wrexham was separated from Liverpool and attached to the North Wales Board of Management.

The site chosen for the factory was the Willow Road Depôt, a two-storied building, originally a malt house, lent rent free by the Wrexham Corporation. In 1917, a further building was rented from a firm of brewers in the town and adapted for varnishing rooms, examination rooms, canteen, &c.

By a formal agreement with the Ministry, signed 22 October, 1915, this factory was administered by the North Wales Board of Management. One works manager was appointed for the three factories administered by the Board.

The proposed output was 500 shells weekly, rising to 3,000; the actual output rose to 1,400 in 1916, 2,000 in 1917, and 4,500 in 1918. The production of 18-pdr. shell was interrupted for a short period in 1916 to take on 13-pdr. shell. In addition, all shell produced either by the Portmadoc and Carnarvon factories or the local contractors were finished at Wrexham. The total deliveries of shell into bond from the factory amounted to 54,600 13-pdr. H.E. and 840,400 18-pdr. H.E. and smoke.

The factory was equipped with about 50 machines, of which about two-thirds were the property of the Ministry, and the remainder hired from local manufacturers.

All the labour was drawn from the town or immediate surroundings; women workers were plentiful, but male labour was scarce. With the exception of parting off, all operations on shell were carried out by women, who, in October, 1918, accounted for 86·1 per cent. of the numbers employed (259).

The capital expenditure to 31 March, 1918, was £9,000.

Portmadoc.—A census made in July, 1915, of machinery available in the North Wales area showed that there were 20 lathes and five drills at Portmadoc. On the strength of this report a sub-committee of the Munitions Committee recommended that one of the shell factories then under consideration should be established in that town.

The plan was eventually approved by the Director of Area Organisation, and the Boston Lodge Works, belonging to the Festiniog Railway were secured at a nominal rent. By an agreement signed on 22 October, 1915, the North Wales Board of Management undertook to manage the factory on behalf of the Ministry. The output of shell was to be 500 a week, rising to 3,900 a week, but the maximum was not attained. In addition to the hired machinery, four new lathes were added by the Ministry.

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[1] D.A.O./Misc./1394; HIST. REC./H/1121.22/5; HIST. REC./R/1121/29.

Female labour was of a good class and plentiful, although many women had to come a considerable distance from their homes to the factory; mess accommodation was very successfully provided for these workers. Of the 61 employees in October, 1918, 49 (80·3 per cent.) were women.

The capital expenditure to 31 March, 1918, was £3,700.

Carnarvon.—Carnarvon was suggested by the North Wales Munitions Committee as the site for the third of the factories which they proposed to establish.

The Vulcan Foundry was taken over from Messrs. Humphrey Owen and Sons, manufacturers of machinery for slate quarries, etc., at a yearly rent of £180. On 22 October, 1915, the agreement, by which the North Wales Board of Management undertook to administer the factory, under the usual conditions, was signed.

The output promised was 500 shells weekly, rising to 3,000. This factory was not, however, well equipped; the hired lathes were old, and although they were reinforced by several new machines, output was considerably hindered.

Here, as in the other North Wales factories, female labour was both plentiful and freely used. In October, 1918, there were 80 workpeople, of whom 64 (80 per cent.) were women.

The capital expenditure to 31 March, 1918, was £2,800.

Nottingham National Shell Factory.[1]

The Nottingham Munitions Committee, formed in March, 1915, approached the War Office on 28 May with an offer to establish a National Shell Factory. Authority to proceed was granted to a Board of Management on 12 June, and the contract was finally signed on 12 July, a reconstitution of the Board having meanwhile taken place in order to make it more representative.

Part of a block of buildings known as Spring Close, formerly used for textile and lace manufacture, was taken for the factory at a rent of £200 and £80 for rates and taxes. Other portions of the same building were later taken over for general offices, stores, engine rooms, etc. The factory was administered by a factory manager acting under the general supervision of the Board.

The factory was originally equipped for an output of 2,000 to 4,000 13-pdr. In September, 1916, a change over to 3,000 2·75-in. a week was made, followed in December, 1916, by a further change to 4,000 18-pdr. shells a week. The total output to the end of 1918 was 346,800 13-pdr. H.E., 1,109,300 18-pdr. H.E. and smoke, and 54,000 2·75-in. H.E. In addition, the factory undertook the copper banding, base-plating and varnishing of the shell produced by the co-operative group, averaging about 12,000 18-pdr. weekly.

As the factory was one of the earliest to start, male labour was easily obtained. Later, when men became scarce, female labour was obtained in abundance owing to the depression in the local textile

[1] HIST. REC./H/1121.24/7; D.A.O./Misc./1394.

trades, and of 538, the maximum number of workers (November, 1917), 84·9 per cent. were women. In September, 1918, there were 434 employees, of whom 81·3 per cent. were women.

The capital expenditure to 31 March, 1918, was £25,800.

Rawtenstall and Bacup.[1]

The Shell Factory (*Irwell Mill*).—On 29 September, 1915, the Rawtenstall and Bacup district, which had hitherto been administered by the Blackburn Board of Management, formed its own committee. A scheme for a National Shell Factory was submitted to the Ministry, who, on 11 December, 1915, authorised a Board of Management, drawn from the committee, to carry it out.

The Irwell Mill, Bacup, a one-storey building formerly used as a weaving shed, was offered, rent free, by Mr. Hargreaves, and with a few structural alterations involving no extensions, was adapted for a shell factory.

An output of 750 4·5-in. H.E. shells a week was originally offered. The maximum output eventually attained was over 2,000, and a total number of 156,900 shells was manufactured.

The plant consisted originally of 40 borrowed lathes not designed nor suitable for shell work. The first copper-banding press was converted from an old brick-making press, while a steam hammer was used for bottling throughout.

Skilled and semi-skilled labour was very scarce, but unskilled labour, consisting of mill operatives, quarrymen, and business people, was ample. Dilution was not at first considered suitable to the district, and was not introduced till the spring of 1917. In October, 1918, the numbers employed were 180, the percentage of women being 65·6.

The capital expenditure to 31 March, 1918, was £7,400.

The Rectification Factory (*Height Barn Mill*).[2]—At the end of 1917 the Board of Management put forward a proposal, which was approved, for the manufacture of 4,000 6-in. shells a week. Vacant premises were secured at Bacup, consisting of a weaving shed and four-storied mill, for which a rental of £50 a year was paid. While equipment was still in progress, in January, 1918, it was decided to abandon the shell manufacture scheme, owing to shortage of steel, and to use the factory instead for the rectification of forgings and shell.

Arrangements were accordingly made to alter the equipment to undertake the rectification of 6-in. shell forgings and 4·5-in. and 18-pdr. shells. Later, the finishing of the 6-in. forgings was also undertaken. Work on forgings began first, in the spring of 1918, and by the first week of June some 1,200 were ready for inspection. Deliveries of rectified 4·5-in. began at the end of June, but output of 18-pdr. was considerably delayed, and had hardly begun at the time of the Armistice. Owing to the varying nature of the defects to be rectified, it was difficult to promise a fixed weekly output, but in July the factory agreed to accept a weekly quantity of 5,000 4·5-in. and 5,000 18-pdrs.

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[1] D.A.O./Misc./1394 ; D.A.O./2/437. [2] D.A.O./2/1238, 1288, 1385.

The numbers employed in the factory were approximately 150, of whom 76 per cent. were women. At the beginning of 1918 an expenditure of £11,000 on the factory was sanctioned. The actual capital expenditure to 31 March, 1919, was £19,500.

Rochdale.[1]

In June, 1915, the Rochdale Committee, at that time affiliated to the Manchester Committee, made overtures towards establishing a national factory. The proposal was held up for some time by the difficulty of obtaining suitable premises, and was finally solved by the offer of the Rochdale Tramway Committee to place a portion of their Tramway Shed (then in process of erection) freely at the disposal of the Rochdale Committee. The offer was accepted, and on 25 October a Board of Management was authorised by the Ministry to organise the factory. The usual agreement was not signed until 17 November, 1915.

The Tramways Committee was represented on the Board, and one of their officials acted as Secretary of the factory. The administration was altered in July, 1916, and the factory was controlled until the close of 1916 by the Superintending Engineer and a member of the Board. In 1917 a committee, appointed by and answerable to the Board, was placed in control.

The factory was to be equipped for the production of 1,000 6-in. shells a week, and delivery was to commence in March, 1916. Owing to delays, mainly connected with the completion and adaptation of the building, the first consignment of shell was not produced until July, and the required maximum output was delayed until November. The total output to the end of 1918 was 90,200.

The question of dilution presented great difficulties in this factory. At the beginning of 1917 the total numbers employed were 366, of whom 62·6 per cent. were women. Recommendations were made to the Board (whose attitude was favourable) to raise the percentage of female labour, but the attempts to introduce women tool-setters led to threats of strike from the skilled workers, and the Labour Department of the Ministry decided in May, 1917, to suspend the question. In October, 1918, the Board was once more advised to proceed with dilution. At the end of the month the percentage of women was 70·9 on a total of 289.

The capital expenditure to 31 March, 1918, was £19,600.

Rotherham.[2]

A local Munitions Committee, composed of Rotherham and Barnsley engineers, was formed early in April, 1915, but owing to difficulties of organisation, resulting eventually in the separation of the two districts, it was not until 26 June, 1915, that the Board of Management was authorised to carry out a scheme for a National Shell Factory.

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[1] HIST. REC./H/1121.22/7 ; HIST. REC./R/1121/29.

[2] D.A.O./3/581, 688 ; HIST. REC./H/1121.23/21 ; (Printed) *Weekly Report*, No. 164, VI, A, (19.10.18.)

The factory occupied two sites. First operations were carried out at the Brinsworth Ironworks, a portion of which was rented by the Ministry for £920 from Messrs John Baker, makers of locomotive wheels, etc. Finishing operations were performed at the Rother Ironworks, on premises rented for £756 17s. 6d., from Messrs. Owen and Dyson, railway wheel and axle manufacturers.

The factory was administered by the Board of Management, two of whose three members represented the lessors of the factory.

Under their agreement, the Board undertook to begin with an output of 500 4·5-in. H.E. shells a week, working up to 2,000. Deliveries began at the end of November, 1915, and reached 5,000 at the end of 1916. During 1917 manufacture was divided between 4,000 4·5-in. H.E. and 1,200 4·5-in. chemical shells a week. The factory reverted to 4·5-in. H.E. in 1918, but shortly before the Armistice arrangements were made to change over entirely to the 4·5-in. chemical shell. The total deliveries were 414,400 H.E. and 10,500 chemical shells.

The original equipment consisted mainly of machines collected from the district, and ill-adapted for shell manufacture.

Early difficulty was experienced with regard to skilled labour. By the beginning of 1916 women were employed on almost every operation throughout the factory, and in October, 1918, the percentage of female labour was 71, the total number of men and women employed being 636.

The capital expenditure to 31 March, 1918, was £53,000.

The Scottish National Shell Factories.[1]

Aberdeen.—The inauguration of the Aberdeen National Shell Factory was unusual. Early in 1917 the Aberdeen Board of Management was controlling a small co-operative group of three contractors, producing between them 1,600 6-in. shells weekly. Of these contractors Messrs. McKinnon undertook the finishing of the entire output. At this date their manager was convicted of certain malpractices in altering shell, and the Ministry decided that the firm must withdraw from the contract. Both the Ministry and the Board were very anxious not to interrupt output, and it was settled that the latter should take over Messrs. McKinnon's shops at 80 Spring Gardens, and run them as a National Shell Factory. The premises were accordingly taken over on 2 March, 1917, at a rental of £1,000 per annum.

The Board entered into a supplemental agreement with the Ministry, authorising them to work the factory as a National Shell Factory. They were to continue to receive their contract price (as a Co-operative Group), paying over to the Ministry the assigned value of that part of the work which was done by the factory. The scheme was a financial success, £22,000 profit being sent to the Ministry between June, 1917, and October, 1918.

Between the middle of 1917 and the Armistice the factory performed the finishing operations and painting of 99,700 6-in. H.E. shells.

[1] HIST. REC./H/1122/54 ; D.A.O./Misc./1394 ; HIST. REC./H/1121.32/2.

The numbers employed in October, 1918, were 119, of whom 42 per cent. were women.

The capital expenditure involved to 31 March, 1918, was £600.

Dundee.—In May, 1915, Mr. West visited Dundee to advise the local Munitions Committee on the best disposition of available resources. On his recommendation it was decided by the committee to propose the establishment of a National Shell Factory. On 1 June their scheme received the formal consent of the War Office, and at the same time a Board of Management, elected by the committee, to administer the scheme, was approved.

Several sites had been suggested by the committee before Mr. West's approval was obtained. The building finally selected was a portion of the jute mills of Messrs. Grimond, of Dundee, by whom they were lent rent free to the Ministry. An adjoining tenement was purchased later and adapted for offices, cloakrooms, etc., making the factory self-contained with its own entrance and exit. A certain number of machines were obtained from the Dundee workshops, but the main equipment was provided from the steamship "Antilla," which had been captured with a cargo of machinery, and was lying in the Dundee Customs House at the time of Mr. West's visit.

The proposed output of the factory was a minimum of 5,000 18-pdr. H.E. shells weekly rising to 15,000. A start was made on production in September, and by November sufficient shells had been delivered into bond to enable proofs to be taken. In July, 1916, the Board was instructed to change over to 2·75-in. shrapnel, and owing to delay in receiving and installing the necessary plant the factory had to be temporarily shut down and its employees dispersed. When a start could be made, fresh workers had to be trained, with a consequent fall in output, 3,980 shrapnel only being delivered in the course of three months. Almost immediately a change back to 18-pdr. was made, and was accomplished without any stoppage of the day or night-shift. In February, 1918, the manufacture of 18-pdrs. was entirely superseded by that of chemical shell burster containers. The entire output of 18-pdr. shell during the two periods of manufacture was 561,100, of 2·75-in. shrapnel 4,300, of 6-in. chemical shell burster containers 579,000, and of 18-pdr. chemical shell burster containers 100,800. In addition, a considerable number of forgings for these different types of shells was made in the factory.

Both output and cost of production in the factory were excellent, and the success must be considered to be largely due to the early advantage of Mr. West's technical advice both in the choice of a site and its subsequent lay-out.

No difficulty was experienced in obtaining a suitable and good class of female and unskilled labour. Skilled labour was always difficult to secure. In June, 1915, thirty turners were sent to train at Elswick. At the end of 1917, 351 workers were employed, 74·3 per cent. being women. In October, 1918, of 427 employees, 325 (76·1 per cent.) were women. The capital expenditure to 31 March, 1918, was £34,000.

The South Wales National Shell Factories.

Uskside[1]—The Uskside works occupy an excellent position on the west bank of the Usk, with sidings connected at two entrances with the Great Western Railway and branch lines to each department. Their immediate pre-war employment was the manufacture of steam and electric mining plant for the Uskside Engineering Company, but already in May, 1915, they had turned over to the production of munitions in the shape of proof shot and 18-pdr. shell. They were suggested at that date by the Welsh National Committee as furnishing a suitable site for a national factory and after some negotiations the Ministry decided to take over the whole buildings as a going concern for the duration of the war. The transfer was formally accomplished on 1 July, 1915. The rent paid was £460 per calendar month. The works were administered by a Board of Management appointed by the Ministry and composed of the former Board of Directors.

The manufacture of 18-pdr. shell which had already begun was continued till the summer of 1917, when production was stopped. A new erecting shop for 6-in. shell had been built before the Ministry took over and in March, 1916, deliveries began and were sent out in regularly increasing numbers till 1918, when the plant was turned over to 4·5-in. shell. The total output from the factory was 24,500 18-pdr ; 119,700 6-in. and 16,100 4·5-in.

The Uskside works were by no means limited to the production of shell and during the Ministry's tenancy they produced proof shot of various calibres and also proof shot forgings, some of these being made from recovered proof shot, other work included gun carriage forgings, pedestals for naval guns, breech pieces for 9·45-in. trench howitzers, and rudders and other gear for standard ships. Moreover, they maintained their pre-war work in carrying out urgent repairs for colliery plants.

The question of dilution, which was introduced into the factory in October, 1915, presented no special difficulty and the women, like the men, kept a shift of about 60 working hours. A canteen, opened in August, 1915, by the Y.M.C.A. assisted by voluntary workers, provided food and recreation for the employees ; from February, 1917, it was administered by the Board of Management. In October, 1918, there were 471 workpeople, of whom 46 per cent. were women.

As little alteration as possible was made to the existing works. The new 6-in. shell shop, however, the cost of which was borne by the Ministry, was fitted with the latest appliances for reducing handling to a minimum, including bench conveyers which, by keeping the shell at the same level as the lathes from start to finish, made it possible to operate nearly the whole shop with female labour. The capital expenditure involved by the adaptation of and additions to the works was £61,900.

Ebbw Vale.[2]—In June, 1915, the Welsh National Committee negotiated a scheme by which one of the shops of the Ebbw Vale Steel

[1] D.A.O./5/505, 510 ; D.A.O./Misc./1394, 238.
[2] D.A.O./Misc./238 ; D.A.O./5/505 ; HIST. REC./R/1121.25/7.

Iron and Coal Company engaged on manufacturing 1,000 18-pdr. shells for Woolwich, should be made a national factory, these shell to form its first delivery.

The premises were offered rent free by the company. The factory was administered by a Board of Management, the Chairman of which was Managing Director of the company.

The promised output was to be 1,000 18-pdr. shell weekly, rising as soon as possible to 5,000. On 11 August, 363 shells had been delivered. Shortly after, Mr. West authorised an extension for the production of 5,000 60-pdr. shell weekly.

By the close of 1915, the effects of certain disadvantages inherent in the scheme began to appear. The factory was 19 miles from Newport and the infrequent train service, together with the heavy congested goods traffic, led to labour and other difficulties which were reflected in very heavy costs of production. In November the cost price of the 18-pdr. shell was 17s. 7d., and in December, 20s. 2d. The Director of Area Organisation under the circumstances strongly advised the abandonment of the 60-pdr. scheme. In spite of the advantages of their early start, the factory had only attained a weekly total of 1,000 shells at this date, and though output slightly increased at the beginning of 1916, costs continued very high. In May, any idea of extension was definitely rejected and the Board warned that drastic measures would be taken unless better results were obtained. In July, 1916, the D.A.O. Executive Committee finally decided to close down the factory. The total deliveries amounted to 89,200 shells.

The capital expenditure to 31 March 1918, was £32,200.

Newport (Maesglas)[1]—In the autumn of 1915, the Ministry decided to establish a second factory at Newport for 60-pdr. H.E. shell. The fitting shops recently completed at the Great Western Railway engine sheds at Maesglas, some two miles out of Newport, were acquired for the purpose. An auxiliary shop for producing the shell noses was also taken over from the Tyne Engineering Works, ship repairers in the same town.

The factory was administered by a Board of Management composed of the same persons as the Ebbw Vale Board but with a different chairman and secretary, and the meetings were held independently. Responsible to the Board were a chief accountant, who also acted as a commercial superintendent, and a factory manager.

Maesglas suffered more than usual from delay in obtaining machinery, and it was not until late in March, 1916, that appreciable progress was made with the erection of plant. Shell began to be delivered into bond in June, 1916, and by November the factory was producing a weekly average of 7,000 shells. The total quantity delivered into bond was 601,200. In addition, 229,700 nose bushes for 4·5-in. and 9·2-in. shell were made in the factory.

The supply of labour presented, at the outset, considerable difficulties, but female labour was abundant, once the question of training

[1] D.A.O./Misc./1394; D.A.O./5/143, 505.

had been surmounted. In March, 1918, when the work was re-organised both to introduce a new Mark of shell and reduce output, considerable trouble was threatened by the necessary change to two eleven-hour shifts for both male and female workers. All male employees, numbering about 1,200, were discharged and were re-engaged as required on the new terms. This resulted eventually in improved earning capacity for the workers, who were paid a day rate plus a production bonus, and the trouble disappeared. In October, 1918, the employees numbered 974, 74·3 per cent. being women.

Owing to the distance from Newport, transport facilities had to be provided for the workers and a service of motor trains, run by the Great Western Railway, was instituted at the cost of the Government. Little adaptation was required for the Maesglas works, but considerable alterations, at Government expense, were made to the shop at the Tyne Engineering Works. Canteens, cloak-rooms and other offices were erected in both works. The capital outlay by the Ministry to 31 March, 1918, was £112,400.

Cardiff.[1]—On 30 June, 1915, the Cardiff Board of Management received ministerial approval for the establishment of a national factory. The site chosen was a brick building hitherto used for spinning hemp and making yarn and rope. Temporary buildings for inspection, bond and store rooms were subsequently added on adjoining sites belonging to the Taff Railway Company, who allowed free occupancy. The factory was situated at the south end of Cardiff within easy distance of tramways, but until a siding was laid into the factory yard, early in 1916, the railway facilities were poor.

The factory was designed for a weekly output of 1,000 rising to 5,000 18-pdr. shells and by the summer of 1916 had produced 37,445 shell. Manufacture then ceased and extensive alterations and adaptations of machinery were made to produce 60-pdr. shellheads, of which 68,913 were machined by the end of 1916, together with a number of 6-in. proof shot. To meet the renewed demand for 18-pdr. shell the factory was again re-laid out on the basis of an output of 5,000 per week. The weekly output eventually reached 7,000, and the total deliveries to the end of 1918 were 497,900.

Skilled labour was fairly plentiful, unskilled labour, both male and female was abundant. The whole of the production and a large proportion of tool setting and gauging was done by female labour, which in October, 1918, represented 78·3 per cent. of the total number employed (470).

The capital expenditure entailed in the setting up of this factory was £28,500.

Swansea.[2]—On 23 June, 1915, a deputation representing the Swansea district of the Welsh National Committee visited the Ministry,

[1] D.A.O./Misc./1394 ; D.A.O./5/503 ; HIST. REC./R/1121.25/6.
[2] D.A.O. / 5 / 504, 534, 523, 600, 197 ; HIST. REC. / R / 1121 . 25 / 8 ; HIST. REC./R/1121/20.

when it was decided to accept their offer to establish a National Shell Factory in the town. Suitable premises at Landore, Swansea, were offered by Messrs. Baldwin, rent free; additional cloak rooms, tool rooms, etc., were partly paid for by the Government.

The factory was administered by a Board of Management authorised by the Ministry on 26 June, 1915. The Managing Director of Messrs. Baldwin was chairman.

The factory was originally intended for 18-pdr. H.E. shell but before the close of 1915, it was decided to produce 4·5-in. as well. In the middle of 1917 the capacity was 4,000 4·5-in. shells and 2,500 18-pdr. a week. In April, 1918, the manufacture of 18-pdr. H.E. was stopped and the factory turned over instead to 18-pdr. steel chemical shell. The total output of 18-pdr. H.E. was 215,100 and of 4·5-in. 419,900.

The factory suffered at the start from an incompetent works manager, and in October, 1915, the plant had to be reconstructed. The results appeared in very high initial costs of manufacture, but in October, 1917, the costs both for 4·5-in. and 18-pdr. H.E. were stated to be the lowest on record for any National Shell Factory.

The total number of workers in October, 1918, was 636, the percentage of female labour being high (87·6). The capital expenditure was £40,500.

Llanelly National Shell Factory.[1]—In September, 1915, Llanelly engineers, who had hitherto been grouped under the Swansea Board of Management, applied for permission to establish a National Shell Factory for 6-in. shell. The request was favourably regarded by the Ministry, and with the approval of the Welsh National Committee for Munitions of War, a Board of Management was nominated which was authorised by the Ministry of Munitions on 27 September, 1915.

The firm of Messrs. Richard Thomas, tinplate manufacturers, the prime leader in the movement, offered to the Board, rent free for the duration of the war, excellent premises known as Burry Extension Works with the use of such plant installed there as might be required for the factory. The site was taken over by the Board as from 19 September, 1915.

The agreement between the Ministry and the Board was signed on 23 October, 1915. The preliminary output was to be 1,000 6-in. shells a week, the first delivery was to be on 1 February, 1916, and was actually made on 26 February. A capacity of 4,500 shells a week was attained by 1917, but in December of that year the factory under their current authorisation, promised a delivery of 2,250 only. By the end of 1918 a total of 381,400 shells had been manufactured.

The capital expenditure to 31 March, 1918, on this and the Rectification Factory was £171,500.

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[1] D.A.O./5/520, 610, 566, 22, 22a; HIST. REC./R/1121/29; (Printed) *Weekly Report, passim.*

Llanelly Rectification Factory.—In September, 1916, it was decided to build a rectification shop to be run by the Board of Management of the Llanelly National Shell Factory.

By a supplementary agreement with the firm of Messrs. Richard Thomas, dated 20 September, 1916, the Board acquired rent free a site adjacent to the Burry Extension Works. A new building was erected here at the Government expense.

It was intended to rectify all shell up to 6 in. and capacity for about 40,000 rectifications a week was provided. This number was never attained, the average for the last half of 1918 being 16,000 6-in. and 18-pdr. shells a week, of which the latter shell comprised the larger number. The total deliveries were 505,900 18-pdr. and 284,000 6-in.

The labour employed at the Shell and the Rectification Factory totalled 1,440 in October, 1918, the percentage of female labour being 73·7.

The West Cumberland National Shell Factory (Workington).[1]—Apart from the delay incidental to the difficulty of organising the county the West Cumberland Munitions Committee at first devoted its energies to establishing a co-operative group and it was not till the close of September that they finally approached the Ministry with a scheme for a National Shell Factory. Acting on the report of the Area Engineer the Ministry gave official sanction on 25 November, 1915.

The site chosen for the factory was the Hawkshead Foundry, Workington, belonging to Messrs. T. A., J., and P. Milburn, which had been standing empty for some years and the factory was lent to the Ministry free of charge, £40 yearly ground rent being payable by the Ministry.

The West Cumberland Board by whom the factory was administered originally offered to produce 2,500 18-pdr. weekly rising to 3,000. Deliveries did not begin till August, 1916, but rose to 4,000 weekly in 1917, eventually attaining a maximum of 4,500. This included a small weekly sub-contract delivery of 500 rough bored and turned shells. The total number of 18-pdr. shells (H.E. and smoke) delivered to bond was 359,400, and a number of 6-in. and 18-pdr. base plates were also machined for other factories. At the date of the Armistice the factory had just turned over to 18-pdr. chemical shell.

This factory was selected by the Ministry in February, 1918, for an experiment in a one break day shift and a 50 hour week. The hours agreed to be worked were from 8 a.m. to 6 p.m. and a start at 7 a.m. on Saturdays. After three months trial the majority of workers were in favour of the experiment in spite of an evident desire for an earlier stopping time; at the end of the second three months there was no doubt about the popularity of the new hours.

The numbers employed in October, 1918, were 181, 84 per cent. being women. The capital expenditure to 31 March, 1918, was £12,700.

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[1] HIST. REC./H/1121.22/2, 3; D.A.O./Misc./1394; HIST. REC./R/1121/29; Vol. II, Part II.

CHAPTER IV.

NATIONAL PROJECTILE FACTORIES.

I. Introduction.[1]

(a) *Initiation of the Factories.*

In July, 1915, deliveries of heavy shell fell far short of promises, and at the same time the necessity of meeting the new gun programme involved a large expansion of output. The weekly programme of shell manufacture aimed at was 39,000 60-pdr. shrapnel; 24,000 60-pdr. H.E.; 41,000 6-in. H.E. and 32,000 9·2-in. H.E., a total of 136,000. At a conference held on 13 July with representatives of 9 armament firms to consider by what means this programme could be attained, it was stated that there was no immediate prospect of increasing output of shell over 4·5-in. to more than 32,000 a week. Discussion at once revealed the impossibility of improving the position by extending existing works, but the firms were strongly opposed to the alternative suggestion for the establishment of national factories independent of them. A solution was found in an arrangement by which the armament firms agreed to build and manage new factories, in connection with their existing works, the cost of building and all manufacturing expenses being paid by the Government. The factories erected under these conditions were known as National Projectile Factories.

Detailed arrangements were under discussion throughout the rest of July. The main provisions of the scheme which was finally evolved may be summarised as follows :—

The factories were to be erected and equipped at government expense, and were to remain the property of the Government. The Government was also to provide raw materials, give any possible assistance in the provision of labour, and be responsible for all working expenses, including wages, with the exception of the salary of the manager. The latter was to be appointed by, and responsible to the managing firm, but the appointment was to be approved by the Minister, who would have the right at any time of recommending the dismissal of the manager or any member of the staff.

As a fee for supervising erection and equipment each firm was to receive a percentage of the expenditure involved, this percentage being fixed at 4 per cent. on the first £250,000, 3 per cent. on the second £250,000, 2 per cent. on the third £250,000, and 1 per cent. on anything over £750,000. On the production stage being reached, each firm was

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[1] Hist. Rec./H/1300/2, 3, 13, 15. For the place taken by these factories in the general organisation for shell manufacture, *see* also Vol. X, Part III.

to receive as remuneration for management and supervision, a fixed sum per shell—5s. for each 9·2-in.; 1s. 6d. for each 6-in.; and 1s. 3d. for each 60-pdr. shell approved—or such sum as might, by agreement, be substituted in order to give direct encouragement to increase of output or economy in production.

This scheme was followed in the agreements under which factories were erected at Cathcart by Messrs. G. & J. Weir; at Dudley by Messrs. Harper Sons & Bean; at Glasgow (Cardonald, Moss End & Mile End) by Messrs. Beardmore; at Hackney Marshes by Messrs. Dick Kerr & Company; at Lancaster by Messrs. Vickers; at Renfrew by Messrs. Babcock & Wilcox; and at Sheffield (two) by Messrs. Hadfield and Messrs. Firth. The only National Projectile Factories which differed, save in detail, from the type were those at Nottingham, where Messrs. Cammel Laird refused to accept any fee for erection or management; and at Birtley where a factory was built by Messrs. Armstrong Whitworth, the agreement with whom was later converted into one with the Belgian Government, who worked the factory with Belgian labour.

Mention must also be made of certain factories which were not erected as National Projectile Factories, but were classed with the group for purposes of headquarters administration. A factory at Darlington, built by Messrs. Armstrong Whitworth at Government expense and managed by the North-Eastern Railway Company as sub-contractors to Messrs. Armstrong, was taken over by the Ministry in the summer of 1916.[1] A factory at Ponders End, where a large output of heavy shell was produced by the Rees Roturbo Manufacturing Company, of Nottingham, from the end of 1914, was taken over in 1918. The factory's output was satisfactory, but misunderstanding had arisen between the company and the manager of the works, and the latter in some cases negotiated direct with the Ministry for contracts, and carried them out although they were repudiated by the company. To put an end to this unsatisfactory state of affairs, it was decided, since the output was needed, that the Ministry should take over the factory. It did not actually come under the control of the Gun Ammunition Department until the beginning of November, 1918, but the arrangement was retrospective as from 31 March, 1917. Though classed as a National Projectile Factory, it was occasionally called a National Ordnance Factory, owing to the fact that in 1918 the most important, though not the largest, part of its output consisted of 6-pdr. guns for tanks and some gun repair was also done. The total shell output from 31 March, 1917, to the end of 1918, was 294,600 6-in. H.E., 299,700 8-in. H.E., and 700 12-in. By 31 March, 1919, a sum of £812,200 had been expended on this factory. Two other factories in the London district, the Ailsa Craig and College Park Works, administered by the Metropolitan Munitions Committee until 1918, were taken over on 1 June of that year, as a result of the decision to transfer the administrative work of the Metropolitan Munitions Committee to the Ministry. At Leeds, a group of factories engaged on shell manufacture were classed as

[1] *See* below, p. 134.

National Projectile Factories for two years, though they were administered as National Shell Factories by the Leeds Board of Management. In 1917, one or two of the Leeds factories undertook gun manufacture and repair, and from the end of that year all of them were known as National Ordnance Factories. The history of the Leeds factories, and of Ailsa Craig and College Park, has been related in the chapter dealing with National Shell Factories.[1]

In close conjunction with the National Projectile Factories was the National Components Factory at Tipton, which was established early in 1917 as a central source of components for these factories. It was originally erected by the Ministry on land lent for the purpose by Messrs. Bean, who undertook to operate it under an agency agreement. The plant for manufacture of shrapnel components, H.E. shell heads and nose bushes was transferred from the National Projectile Factories and the works were subsequently turned over to the manufacture of fuses.[2]

(*b*) *Construction.*

Preliminary estimates of the cost of buildings and plant for eight factories drawn up in September, 1915, amounted to over £5,000,000, and it was recognised that this figure would probably be exceeded. Later, with the addition of three more factories, the capital cost was estimated at about £7,000,000. In view of this heavy expenditure, it was decided in October, 1915, that the land on which the factories were erected should either be purchased outright or taken on a long lease. As the Minister of Munitions had no legal power to hold land in his official capacity, land was conveyed to the Secretary of State for War in cases where it was intended to be used permanently for military purposes, or to the Office of Works, possession and control being then given to the Minister by a formal departmental minute. In every case except one, definite agreements were reached as to sites, and the Ministry became either owner, lessee for 21 years, or tenant for the duration of the war. At Cathcart, however, the owner of the site had given an undertaking to the feuars of the neighbouring property that no industrial buildings should be erected on the ground, and the land had, therefore, to be taken under the Defence of the Realm Act.

In the case of all the Projectile Factories save one (Mile End, Glasgow) new buildings were erected. Construction contracts were arranged by the armament firms concerned, who were responsible for designing the buildings, but drawings and estimates were submitted to the Ministry for approval. The work of erection was supervised by the Office of Works until October, 1915, when the Director of Factory Construction assumed the responsibility. Construction began in the autumn of 1915, and the factories came into operation at various dates in the course of 1916, the first to begin production being Messrs. Firth's factory at Sheffield, and the last, Moss End.

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[1] *See* above, p.105 and p.111.

[2] C.S.M. 29758.

(c) *Administration.*

In May, 1916, a National Projectile Factories Executive Committee was set up in the Ministry to deal with questions of vital importance or special difficulty arising in connection with the factories. The matters which came before the committee included changes of design, alterations to contracts, requests for additional capital expenditure, the supply of labour and of small tools. In January, 1917, the committee was merged in the Shell and Components Manufacture Executive Committee, which dealt with all questions relating to shell production until the end of the year, when it was dissolved on the formation of the Munitions Council. Executive action with regard to the Projectile Factories was taken by a section of the Shell Manufacture Department.

A resident engineer was stationed at each factory to watch the technical side of production. Elaborate and detailed returns were required from the factories. The statements submitted each week included details of the number of machines available for, and the time taken in, each operation; the number of shell rejected, distinguishing between rectifiable shell and scrap, the total output of forgings and the average output per press and per worker. In addition to the weekly returns, an efficiency chart was filled in monthly giving details of the labour employed, the number of machine hours worked, the total output of shell, etc. From these data a comparative table was drawn up showing the work of all the factories, classified according to the nature of shell made. This efficiency system is interesting, apart from its practical results, as an example of the application of the principles of scientific management on a scale hitherto unknown in England.

Occasionally, when the management of a factory proved unsatisfactory, the Ministry exercised its right of requiring a change in the supervisory staff. Reorganisation was carried out at Cardonald in August, 1916, and at Dudley a year later, and a new general manager was appointed at Lancaster in January, 1917. At Hackney Marshes, prolonged attempts to secure improved organisation were unavailing, and the Ministry took over the direct control of the factory in August, 1917.

The Ministry also exercised supervision with regard to the equipment of the factories. The firms were at first allowed to order machine tools from what sources they chose, though Ministry approval of all orders was required; but later a considerable amount of allocation was necessary, and each firm was obliged to take some American machinery. Control over machine tools became increasingly stringent, and from August, 1916, orders for spare parts as well as for new tools had to be submitted for approval. Considering the Projectile Factories as a single productive group, the Ministry also exercised the right of balancing plant. Factories were periodically inspected and idle machinery recommended for transfer elsewhere. The best possible use of the small tools available was secured by representatives of the Small Tools Section stationed at each factory.

Throughout 1916, the Projectile Factories had priority over National Shell Factories and contractors for the supply of both machinery and raw materials. Shortage of the latter, however, hampered most of the factories, particularly at the end of 1916 and beginning of 1917. At Dudley, for example, the 6-in. forges were idle for this reason during the first week of January, 1917, and a number of machines were idle the following week at Hackney Marshes.

(*d*) *Work done by the Factories.*

The natures of shell which it was originally intended should be manufactured in National Projectile Factories were 60-pdr. H.E. and shrapnel, 6-in. H.E. and 9·2-in. H.E. Subsequently, 8-in. was substituted in some cases for 9·2-in., while 12-in. was undertaken in Messrs. Babcock and Wilcox's factory at Renfrew. The factories confined themselves to medium and heavy shell until early in 1917, when a reduction of the shell programme placed some of their machinery in excess of requirements. In order to utilize this surplus capacity without distributing the machinery, work of various types was undertaken during 1917. Guns were repaired at Lancaster, Cardonald, Sheffield (Hadfield's), Nottingham, and Leeds, and gun parts were made at Dudley. 18-pdr. shell was produced at Cardonald, Mile End, Dudley, and Darlington ; 4·5-in. H.E. at Sheffield (Firth's) ; grenade mortars at Lancaster ; and a certain quantity of Italian shell (149 mm.) at Nottingham. Some aero-engine work was done at Dudley. In 1918, 6-in. chemical shell was produced by Cardonald, Mile End, Hackney Marshes and Dudley, the last having started this type of shell during the previous year, and 4·5-in. chemical shell was produced by Sheffield (Firth's).

In a few cases the entire capacity of a factory was, on the reduction of the shell programme, diverted to new work. Cathcart gave up shell manufacture in May 1917, and turned over to aeroplane work. Nottingham, starting gun repair early in 1917, later turned to gun manufacture ; shell production gradually ceased and the factory was classed as a National Ordnance Factory from 1 October, 1917, though some shell were produced until the middle of the following year. Messrs. Hadfield's factory at Sheffield also made guns in addition to repairing them, and became a National Ordnance Factory in 1918.

The total output of the principal types of shell produced by the factories during the war is shown in the following table, the figures in which include the whole shell output[1] of the Leeds factories, classed as National Projectile Factories for headquarters purposes ; the output of Darlington from the date of nationalisation (1 July 1916) ; that of Ponders End from 31 March, 1917 ; and that of Ailsa Craig from 1 June,

[1] The output was 144,000 4·5-in.; 992,200 6-in.; 13,800 8-in.; 431,300 9·2-in.; 6,600 12-in. ; and 7,300 15-in.

1918. Details of the output of individual factories will be found in Appendix II.

Nature of Shell.	1915.	1916.	1917.	1918.	Total.
18-pdr. H.E.	—	—	464,700	83,200	547,900
S.	—	—	454,400	609,400	1,063,800
4-in. H.E.	—	—	—	16,200	16,200
4·5-in. H.E. and Chemical.	37,300	105,200	583,800	651,700	1,378,000
60-pdr. H.E. and Chemical.	—	491,800	815,600	1,215,000	2,522,400
S.	—	527,500	1,159,300	1,450,600	3,137,400
6-in. How. H.E. and Chemical.	—	864,800	2,921,700	4,138,300	7,924,800
8-in. How. H.E. ..	—	234,100	957,500	871,100	2,062,700
9·2-in. How. H.E. ..	—	328,100	736,600	378,200	1,442,900
12-in. How. H.E. ..	—	4,900	2,000	6,500	13,400
15-in. How. H.E. ..	—	1,400	4,600	1,300	7,300
Grand Total ..	37,300	2,557,800	8,100,200	9,421,500	20,116,800

The table illustrates the rapid increase of state manufacture during the years 1916 and 1917. From a small quantity of one type of shell produced by one factory (Armley Road, Leeds) in the second half of 1915, the output of the National Projectile Factories rose to over 2½ millions in 1916, half of this being produced in the last three months of the year. The 1916 output was more than trebled in 1917, and in this year the maximum output of some of the heavier types (8-in., 9·2-in. and 15-in.) was attained, the 1918 figures showing a comparatively small increase on the aggregate.

(*e*) *Labour.*

Shortage of skilled labour was a difficulty which beset all the factories, although their requirements had priority. In the summer of 1916, a small proportion of skilled tool-room staff was transferred from factories turning out lighter shell, and also from the machine tool trade, but this did not entirely obviate the difficulty. As regards unskilled labour, some of the factories, such as Lancaster, Nottingham and Messrs. Firth's at Sheffield, employed women from the start, Messrs. Firth's factory, in particular, producing excellent results. Other factories were strongly opposed to the extension of dilution, notably Hackney Marshes, a factory which throughout suffered from labour troubles. Difficulty was also experienced in getting some of the factories to accept war munition volunteers.

In March, 1917, female labour represented 39·6 per cent. of the total employees (about 55,000) ; but at the time of the Armistice the proportion was higher, the percentage of women in October 1918 being 50 per cent.[1] on a total of 39,500. In addition, the total number of employees in the Tipton Fuse Factory in October 1918 was 3,104 and 65·6 per cent. of these were women.

(*f*) *Expenditure and Costs.*

The result of the first year's working of the National Projectile Factories was shown when their accounts up to 31 March 1917, were investigated. The average cost of shell produced compared very favourably with the average contract price for the same period. For instance, 60-pdr. H.E., cost 43s. 8d. compared with the contract price of 51s. 3d.; 8-in. H.E. 100s. 7d. compared with 156s. 3d.; and 9·2-in. H.E. 170s. 10d. compared with 217s. 6d. The total output from the group—3,800,000 shell—had cost approximately £13,600,000 to produce, or £14,660,000 allowing for depreciation and management commission. Compared with contract rates, this showed a saving of £2,750,000, and it was estimated that this sum would meet the difference between the capital cost (calculated at £6,830,000) and the probable realisable value of the factories. On only one factory, Hackney Marshes, was there an actual loss in working, while Messrs. Beardmore's factories at Glasgow had effected a saving over contract prices sufficient to wipe out their capital cost and leave a margin.

This result was considered satisfactory for a period which included starting up and during which economy had to be subordinated to output. It could, moreover, be claimed for the factories that they had effected a further indirect saving by producing shell which would otherwise have had to be ordered at high prices in America, while their cost returns had provided valuable data for reducing contractors' prices for the larger natures of shell.

As has been seen, the capital cost of the factories was estimated in 1915 as about £7,000,000. The actual capital expenditure on the group up to 31 March 1918, amounted to approximately £7,390,000. This sum includes the cost of conversion of plant at Nottingham and Sheffield (Messrs. Hadfield's factory) which turned over to gun work at the end of 1917. The expenditure on the factory at Darlington is also included, but that on the Leeds factories and on Ailsa Craig and College Park is comprised in the total for National Shell Factories.[2] In addition, the expenditure on the Tipton Components Factory amounted to £310,800, while by 31 March 1919, £812,200 had been spent on the Ponders End factory.

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[1] The figures for March, 1917 do not include Darlington ; those for October, 1918, include Ailsa Craig and College Park and exclude Leeds, Nottingham and Sheffield (Hadfield's) all of which were then classed as National Ordnance Factories.

[2] *See* above p. 93.

II. Individual Projectile Factories.

Birtley National Projectile Factory.[1]

In July, 1915, Messrs. Armstrong, Whitworth undertook to erect at Birtley, near their Elswick Works, two factories, one to produce shell and the other cartridge cases. Sites were selected near the North-Eastern Railway Station, on the high road from Newcastle to Durham, and close to a colliery and a large electric power station. The area occupied by the Projectile Factory was 52 acres 3 roods; by the Cartridge Case Factory, about 9 acres. The land, which was agricultural, was taken over under the Defence of the Realm Act, but the site of the Projectile Factory was subsequently purchased, the cost being about £24,137.

An agreement on the ordinary National Projectile Factory lines was concluded with Messrs. Armstrong, but in August a novel factor was introduced, when approval was given to a suggestion that the Birtley factories should be worked by Belgian labour. Three Belgian engineers undertook to find sufficient labour to staff the factories, to make arrangements for housing, and to act themselves as joint general managers of the technical departments, responsible to Messrs. Armstrong, as the agents of the Ministry. The progress made in securing labour and in housing construction was not satisfactory, and in November a Ministry representative was appointed to take charge of the recruiting of Belgian workmen. By the end of the year it was apparent that the Belgian managers could not fulfil their bargain, and they were superseded. It was felt to be desirable, however, in order to avoid friction, that the Belgian workmen should be under Belgian control, and the Belgian Government were therefore approached on the subject of management.

An agreement between the British and Belgian Governments was signed in February, 1916. The Belgian Government undertook to manage the factory and provide labour, while the British Government were to pay all expenses, including wages, and to provide material. A British representative was to be stationed at the factory to be responsible for financial matters and for transport and to act as intermediary between the Belgian management and the Ministry of Munitions. The Belgian Government expressly desired to work in direct conjunction with the British Government, without the intervention of Messrs. Armstrong. The firm accordingly relinquished their management of the Projectile Factory, though they completed its erection and agreed to act in a consultative capacity if required. Moreover, it was decided to abandon the original project for a shell factory and a cartridge case factory under one management, and the cartridge case factory was retained by Messrs. Armstrong. It was walled off from the Projectile Factory

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[1] HIST. REC./H/1122.4/3; HIST. REC./R/400/57; M./Demob./143; (Printed) *Weekly Report, passim.*

and rented by the firm who worked it with British labour under a contract agreement.[1]

The construction of the Projectile Factory was practically complete by the end of April, 1916, but delays occurred in the delivery of machinery. The factory was in working by the end of August, 1916, save that the forging presses did not give a satisfactory output until the end of the year. The factory was laid out for 8-in. and 6-in. H.E. shell and for 60-pdr. shrapnel. Deliveries of 6-in. began in July, 1916, of 60-pdr. at the end of August, and of 8-in. in the middle of September. By February, 1917, the promised maximum output was attained for all three natures, viz.—4,000 8-in., 8,000 6-in., and 6,000 60-pdr. per week. In the spring of 1917, 4·5-in. H.E. was begun, instead of 60-pdr., but the latter was taken up again in 1918, and both natures were produced for some months. In 1918, also, 4-in. anti-aircraft shell were produced; 3·7-in. and 8-in. proof shot were undertaken; and some experimental work was done on 6-in. stream-line shell. The 2,000,000th shell made by the factory was delivered at the beginning of June, 1918. The total output of the principal types produced by the factory to the end of 1918 amounted to 2,806,800 shell, the largest output being of 6-in. H.E. (1,292,000). The output of 8-in. H.E. was 637,300; of 4·5-in. 399,300; of 60-pdr. shrapnel 461,000 and of 4-in. 16,200. Work closed down immediately after the Armistice, and all forging operations had completely stopped by the third week in November.

One of the conditions of the agreement with the Belgian Government in February, 1916, was that 1,000 skilled men should be released from the Army, and throughout a large proportion of the men employed at Birtley were of military age. There were very few women workers: in April, 1917, out of 3,708 employees only 36 were women, while in October, 1918, there were 3,826 men and no women. Day and night shifts were worked, but there was no Sunday labour. Piece work rates were as a rule paid, the rate being the normal trade union one for the work in question. At the end of 1916, a bonus on production was granted to foremen and chargemen. As there were no restrictions on output, high wages were accompanied by large output and by low costs of production. An account is given elsewhere[2] of the village which was constructed to house the Belgian workmen and their families. The repatriation of the Belgians began as soon as possible after the Armistice, and arrangements were made for 1,500 to leave England in the first week of December.

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[1] 94/National/103. A somewhat similar arrangement was made late in 1917 in connection with the scheme for a so-called "Government Cartridge Case Factory" at Long Eaton; but in this instance, the Ministry was to bear the initial cost of establishing the works, which were to be rented and operated by Messrs. Fenton Bros. at fixed contract prices, while the Ministry was to receive one-half of the profits. The project was, however, abandoned in the spring of 1918. (Printed) *Weekly Report*, No. 121, 1, p. 5.

[2] Vol. V, Part V.

The estimate of the cost of the factory given by Messrs. Armstrongs in the autumn of 1915 was higher than that of any other National Projectile Factory yet received. The firm attributed the high cost largely to the purchase of American machinery and to the provision of electric power cables from the main station to sub-stations on the site of the factory. The actual capital expenditure on the factory up to March, 1918, amounted to £892,800, including the cost of the site.

Cathcart National Projectile Factory (Messrs. G. & J. Weir).[1]

Messrs. G. & J. Weir undertook to erect and manage a National Projectile Factory at Cathcart as part of the Glasgow Shell Scheme,[2] and a suitable site was found in a grass park opposite the firm's works in Minto Avenue. The land was the property of Sir John Stirling Maxwell, and in consideration of certain moral obligations which bound him not to lease it for industrial purposes, the Ministry took over the site under the Defence of the Realm Act.

Agreements for erection and management were drawn up on the lines common to National Projectile Factories, and the firm undertook to machine 2,000 8-in. shell weekly, the forgings being supplied by the Ministry. By 5 February, 1916, the main buildings were nearly completed, though some delays occurred in obtaining the necessary electric power from the Clyde Valley Company, and the power plant was not actually completed till 3 June, 1916. By April, 1916, preliminary operations on shell were begun and the machines were being run to train the workers. In May, the factory was completing unfinished shell from Cardonald, and by 10 June, 1916, the first hundred shells were produced by the factory. A shortage of forgings hampered production in September, 1916, but the promised maximum was reached by November, and early in 1917 the average weekly output was over 3,000. After 12 May, 1917, when the total output had reached 94,200, shell manufacture ceased entirely as the factory was put at the disposal of the Controller of Aeronautical Supplies, an arrangement being made by which the plant was stored and the firm rented the factory from the Ministry in connection with their contracts for aircraft.

The equipment of the factory was retarded in April, 1916, by lack of skilled labour. The original estimate of the staff required was 45 skilled men and 500 unskilled, but in June, 1916, women were being trained, and the managers reported a serious lack of skilled men. In March, 1917, women formed 61·2 per cent. of the total employed (1,044).

The capital expenditure on the factory was very roughly estimated in September, 1915, as £105,000. The actual capital expenditure to March, 1918, was £36,100.

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[1] 94/National/47, 110.; D.D.G.A. 21, 582; HIST. REC./H/1121.3/2. (Printed) *Weekly Report, passim.*

[2] Vol. II, Part II, Chap. XIII.

Darlington National Projectile Factory (North Eastern Railway Company).[1]

A factory at Darlington was taken over by the Ministry on 1 July, 1916. The factory occupied about 2 acres of land belonging to the North Eastern Railway Company, within the area of their locomotive works. Up to the date of nationalisation the North Eastern Railway Company produced 18-pdr. H.E. shell as sub-contractors to Messrs. Armstrong, Whitworth, the factory having been erected in the summer of 1915, by Messrs. Armstrong, but at government cost. The buildings and plant were therefore from the beginning the property of the Government, and the decision to nationalise the factory simplified the position of the railway company by placing them under the direct control of the Ministry of Munitions.

An agreement signed in May, 1917, by the Ministry of Munitions, the railway company, and Messrs. Armstrong provided that the Ministry should bear the entire cost of working the factory and should pay to the railway company 12½ per cent. of such cost to cover supervisory charges, this being the usual arrangement with railway companies making munitions. Rent, not exceeding 5 per cent. of the cost of the land, was to be paid for the site of the factory. The railway company were already under an obligation to take over the factory at the end of the war, if required to do so. The general intention of the agreement was stated to be that the railway company should neither make any profit nor sustain any loss.

Owing to the fact that the managing firm was a railway company this agreement had some provisions not common to national factory agreements, the type to which it most closely approximated being that for National Projectile Factories. Until the summer of 1918, the factory was generally known as a National Shell Factory, although it was not administered by the Area Organisation Department; certain negotiations being effected through the War Manufacture Sub-Committee of the Railway Executive Committee, as was the case with other railway companies. From 1 June, 1918, the factory was controlled by the section responsible for National Projectile Factories.

Up to the time of nationalisation the factory had produced 30,000 18-pdr. H.E. shells a week, but after it was taken over it changed to 18-pdr. shrapnel. Output of this varied according to requirements, beginning in the late autumn of 1916, with 8,000 a week. Early in 1917, 6-in. gun H.E. shell was also undertaken, and in the summer of 1918, the average weekly output was 18,000 18-pdr. and 1,300 6-in. The total output between the date of nationalisation and the end of 1918 was 1,063,800 18-pdr. and 116,700 6-in. Other work undertaken included the repair of fired primers, and, in 1918, the manufacture of cast iron practice shot for the Admiralty.

Foremen and skilled men were supplied by the railway company from their locomotive shops, and trained, in the early days, by Messrs. Armstrong. Unskilled labour was supplied by women, who in the

[1] Contracts/Firms. A/2224; 94/Railways/7; C.S.M. 21618; C.G.A./Misc/66; A.M.3.C./Darl. Rep. /11; A.M.3./7097.

summer of 1916 numbered about 1,400. During the interval of some months which elapsed between the cessation of H.E., and the beginning of shrapnel, manufacture, these girls were dismissed and were re-engaged as required. In the spring of 1917 only one shift, employing about 480 women was being worked, but more labour was taken on when requirements for shell increased, and in October, 1918, the employees numbered 992, of whom 813 (81·9 per cent.) were women.

The capital expenditure on the factory up to March, 1918, amounted to £106,400.

Dudley National Projectile Factory (Messrs. Bean & Sons).[1]

The land required for the National Projectile Factory at Dudley was bought from Mr. and Mrs. Bean and Mr. Edward Harper for £13,866 18s. This price included a large house which could be adapted for administrative officers. The site was on a hill to which railway access was impossible because of the steep gradient, but it was near the agent's works and was the best available. A road dividing the site was reserved for the sole use of the Ministry, and compensation was paid for damage to the town roads caused by motor transport from Dudley stations.

Messrs. Harper Sons & Bean undertook to manage the factory in accordance with the scheme initiated in July, 1915, though to distinguish between their own firm's work and the national factory, as managers of the latter they were known as Bean & Sons. In August, 1917, a thorough reorganisation of the management was successfully carried out.

On 16 August, 1915, the Ministry authorised the firm to proceed with the work and construction began. Quick progress at first produced optimistic promises, but the buildings were not actually complete till 27 May, 1916. The forging-shop, originally most advanced, had much steelwork blown down in a gale at Christmas. Machine delivery was good but erection slow though temporary power was secured from the adjoining works. The factory was planned to produce 6,000 6-in. H.E. (Mark III) and 15,000 60-pdr. shrapnel (Mark II) weekly, and this maximum was to be attained in August, 1916. In March, 1916, a contract placed with the firm for 70,000 60-pdr. shrapnel was transferred to the national factory, adding an extra temporary allocation of 2,000 weekly. Production of shrapnel shell began early in the year, the first delivery being bonded by 13 May, 1916. The output was slow at first, rising gradually from about 1,700 a week in May to an average of 10,000 in September, 1916. Work began on the 6-in. shell on 28 April, but none were bonded till the week ending 12 August. The maximum output promised of each nature was reached by 25 November, 1916. Great difficulty was experienced in starting up the forging shop, and forgings were obtained from other firms until September, 1916, when all the presses were at work. The factory did not fulfil its original intention of manufacturing its own component parts. The difficulties frequently experienced by the Ministry in providing adequate supplies of components and raw material

[1] (Printed) *Weekly Report, passim.*; HIST. REC./H/1122.4/5.

became acute at the end of 1916, and the 6-in. forges, on the verge of stopping early in December, were actually idle the first week of January, 1917. This month the promises of output were raised to 7,500 H.E. shell and 17,000 shrapnel. Throughout 1917 the 6-in. weekly output remained at about 7,000 while in January of that year an urgent Admiralty order for 4,000 6-in. chemical shells (smoke) was undertaken. Lack of components delayed their completion till after 18 May, when the factory was instructed to turn over the extra capacity to 6-in. H.E. and steel chemical shell.

Negotiations followed for a weekly output of 10,000 6-in. chemical Mark III (lethal or lachrymatory) and the first lot of this shell was bonded by 1 September, 1917. Shortage of containers prevailed till November, but the factory then turned over the entire 6-in. production from H.E. to chemical shell, aiming at 15,000 weekly. The output of 60-pdr. fluctuated between 15,000 and 18,000 till March, 1917, when part of the plant was turned over to 18-pdr. shrapnel and H.E. shell; but as great difficulty was experienced in the forging, both presses and furnaces being quite unsuitable for so small a type of shell, the programme was abandoned in September, 1917. The best weeks' deliveries of 18-pdr. shell barely reached 10 per cent. of the estimated output and from October, 1917, it was decided to concentrate on 6-in. chemical and 60-pdr. shrapnel of which the former was to be worked up to 15,000 and the latter to at least 20,000 weekly. Production of these two types increased steadily till February, 1918, when in view of the steel shortage the shrapnel output was curtailed. Through 1917, the factory had also been engaged on gun repair, and in March, 1918, some of the shrapnel plant was taken over for aero-engine work in connexion with Rolls Royce contracts. At the end of June, 1918, the factory suffered seriously from the influenza epidemic. Throughout the autumn the output remained at about 15,000 of each nature. While shell production was brought to an end towards the close of the year, 900 workers were retained on aero-engine work in 1919. The total output of 6-in. H.E. and chemical shell produced up to the end of 1918 was 980,800; of 60-pdr. shrapnel, 1,441,200; and of 18-pdr. H.E. 37,200.

Though labour trouble was not anticipated, it was a perpetual difficulty at Dudley from the beginning. Navvy labour for construction was hard to obtain as other big firms in the district paid at higher rates, and as early as 25 September, 1915, a two days strike of excavators retarded work. In January 38 soldiers were at work on erection, and in June, 1916, a military working party was employed on production. The staff required was estimated as 500 skilled, 1,500 unskilled, and 1,450 women (3,450), but lack of skilled labour was felt during the summer of 1916 and unrest prevailed in November, 1917. Of the 5,767 employees in October, 1918, 44·4 per cent. were women.

The cost of erection and equipment was estimated in August, 1915, as £332,606 but this was already much exceeded in January, 1916, when the total amount paid, including the purchase of land was £483,485. By March, 1918, the capital expenditure was £788,000.

Glasgow National Projectile Factory (Messrs. Beardmore).[1]

After the meeting of armament firms in July, 1915, Messrs. Beardmore & Company, of Glasgow, undertook to produce 4,500 9·2-in., 6,000 6-in. and 6,000 60-pdr. H.E. shells weekly from a group of three factories at Cardonald, Mossend and Mile End, controlled by them through one general manager. All the forgings were to be made at Mossend, the 9·2-in. were to be machined at Cardonald (originally known as Craigton), and the 6-in. and 60-pdr. shell at Mile End, Bridgeton. The agreements for erection and management followed the usual lines for National Projectile Factories, but in October, 1917, the firm agreed to waive any further claim to the management remuneration allowed, only charging the general manager's salary to the Ministry.

Mossend.—The land at Mossend was adjacent to Messrs. Beardmore's existing steel furnaces, and was the private property of Sir William Beardmore, who offered, first, its free use for the period of the war and a short while afterwards, and then, at the Ministry's request, a 21 years' lease at a nominal rent. Building and equipment proceeded very slowly, and no forgings were produced till the autumn of 1916, as owing to the difficulty of steel supply the Government did not press for the factory's completion. Women were employed on forging from the start, but traffic congestion and lack of material hampered the factory's development till March, 1917. In October, 1918, there were 840 employees, of whom 30·5 per cent. were women.

Cardonald.—The site at Cardonald covered 8¼ acres, and was purchased from Sir William Beardmore for £9,862. In September, 1915, the firm agreed to undertake 6,000 8-in. shells instead of the 4,500 9·2-in., and forwarded requirements accordingly. Construction was hampered by bad weather in November, 1915, and the machine-shops did not start work till the middle of March, 1916, when forgings were obtained temporarily from the North British Locomotive Works, pending Mossend's completion. In the last week of May, 1916, Cardonald sent 50 unfinished shell to Cathcart, and the first completed shell were delivered by 10 June, 1916. Output gradually increased in July, and the promised maximum was attained by 23 September, 1916. The supply of forgings was still short, and in November the factory was still being supplied from outside, though Mossend had started work. Labour was increased in December, 1916. In January, 1917, the promised maximum rate was raised to 12,000 shells weekly, and the output rose rapidly, reaching over 15,000 weekly by 17 February. In April, 1917, the revised shell programme involved reduction in the output of large-sized shell, and part of the Cardonald 8-in. capacity was turned over to produce 30,000 18-pdr. weekly. The 8-in. output dropped in May, 1917, to an average of 4,083, and by 11 August the first thousand 18-pdr. shells was bonded; but after October, 1917, the 8-in. maximum was raised to 24,000 weekly at the

[1] 94/Nat./10, 74, 131; C.R./DGSG/2398, 2549; D.F.C./C/66; (Printed) *Weekly Report, passim.*

expense of the 18-pdr. production. Until October, 1917, the factory was also undertaking gun repair at the rate of 80 18-pdr. guns monthly. In January, 1918, the 8-in. shell output was 13,348, and owing to the further change in programme, no effort was made to increase this, but the next month some 8-in. machines were adapted to produce 5,000 6-in. chemical shells weekly, while the managers were instructed to reduce the 8-in. output to 10,000. By 6 April, 1918, 6-in. cast-iron chemical shell were started, and the work improved rapidly, about 4,000 weekly being delivered in May, 1918, when the 8-in. capacity was further reduced to 5,000, and the estimated maximum of chemical shells fixed at 10,000 weekly. This output was reached in August, 1918. The total output of 8-in. shell during the war was 1,008,100, while the 6-in. chemical and 18-pdr. shells produced numbered 319,800 and 50,900 respectively.

In April, 1918, schemes were put forward to extend the factory for the building of at least 10 tanks weekly, in addition to the shell programme ; but output had not been obtained before the cessation of hostilities.

The full staff of the factory was estimated in March, 1916, at 140 skilled and 1,400 unskilled men, and no difficulty seems to have been met as to labour until December, 1917, when some unrest among foremen retarded the 8-in. work. The management was a matter of more difficulty at first, and much discussion over its relation to the unsatisfactory output took place in June, 1916, but by 5 August a thorough reorganisation of the supervisory staff was completed and good results followed. Women were employed later and formed 63·3 per cent. of the total employed in October, 1918 (3,517). As both housing in the town and accommodation at the factory were most inadequate, plans were brought forward, in 1918, for extending the welfare buildings, and erecting a hostel for women, but the scheme was dropped after the Armistice.

Mile End.—For the 6-in. H.E. and 60-pdr. machine shops an existing cotton mill adjoining the Caledonian Railway at Mile End, or Bridgeton, was rented from Messrs. Grant for £1,800 per annum, plus £9,000 compensation for the removal of machinery; £7,500 was also required to strengthen the building.

Instruction in machining began during the week ending 19 February, 1916, and the next month 160 were at work on production, the ultimate staff being 140 skilled men, 20 unskilled, and 1,400 women. By 17 June 630 60-pdr. and 345 6-in. shells were bonded, and the output increased gradually through the summer, though not so rapidly as had been hoped. The promised 6,000 of each type was reached by 28 October, 1916, but in November a slight decrease in the 6-in. output attended the change over to bottled shell. In January, 1917, the estimated output was raised to 7,000 6-in. and 8,500 60-pdr., and these numbers were attained before the end of the month. In April, 1917, Mile End undertook 25,000 18-pdr. out of the 75,000 weekly then allocated to Glasgow, and the first delivery was bonded by 24 May, three months ahead of Cardonald. A steady improvement was maintained through

the summer, and in October, 1917, the maximum output possible from the 6-in. plant was reached. In February, 1918, the 18-pdr. production ceased, and the machinery turned over to 60-pdr. work. In April, 1918, a partial change over was made to 6-in. steel chemical shell, and by June, 1918, the factory was producing 10,000 6-in. H.E., 2,000 6-in. chemical, and 4,000 60-pdr. weekly. In the autumn the 6-in. plant was gradually adapted for making 60-pdr. shell, the output of which was 14,000 weekly by the end of October, when the employees numbered 2,914, 54·3 per cent. being women. The factory's total output of 6-in. shell (H.E. and chemical) was 868,800; of 60-pdr., 679,600; and of 18-pdr., 459,800. The factory closed down at the end of the year without trouble.

The estimated cost of buildings at Mossend and Cardonald was £45,660 and £86,667 respectively, but by March, 1918, the capital expenditure on the three factories was £1,107,600.

National Projectile Factory, Hackney Marshes (Messrs. Dick Kerr).[1]

The preliminary work for the National Projectile Factory at Hackney was started later than most, as the site originally chosen on Hackney Downs had to be abandoned owing to the objections raised by the London County Council to the use of park land. By 25 September, 1915, a new site was found on Hackney Marshes, and the Council granted its free use till the end of the war. Cleaning began on 15 October, 1915, and progressed rapidly; two of the four units were built by 8 January, 1916, and though delivery of machines was slow, the whole structure was complete by 26 February, 1916.

Until the forging shop was in working order the firm supplied forgings and base-plates from their own works to utilize the machines erected and train labour. Shell production began in the middle of February, 1916, and by 1 April, 324 workers were being trained, while the managers hoped to produce 4,000 shell weekly by the end of the month. Though not the first to begin shell-turning, Hackney's first few weeks' deliveries were greater than those from any other National Projectile Factory. It was laid out to produce 15,000 6-in. Mark XVI, and by May, 1916, a total of 1,771 was delivered, but after this month only Mark IV was produced. By 3 June, 1916, the output reached 1,000 weekly, but partly owing to the lack of skilled labour the rise was not as rapid as had been expected from the good start. Prolonged attempts at reorganising the management were begun, as investigation showed an inadequate development of central organisation and the employment of unsuitable labour, while the managers had no hope of reaching the full output before the end of the year. In spite of some attempts at improvement the average output for August, 1916, was only 6,449, and in November 13,300 weekly. In December, 1916, the factory's capacity was re-estimated as 16,000 weekly, and after a temporary drop due to steel shortage this number was delivered in the week ending 6 January, 1917. The next week 111 machines were idle owing to lack of steel, and when supplies of American steel were

[1] HIST. REC./H/1122.4/4; 94/National/4. (Printed) *Weekly Report, passim.*

forwarded the factory found much difficulty in forging it. The cost of the 6-in. shell, in comparison with that in other factories, was very high, and from 1 August, 1917, the Ministry took over direct control of the factory—an alternative already proposed in the summer of 1916. The new manager appointed effected some improvements, though the output remained less than was expected for the rest of the year. In October, 1917, the factory began producing 6-in. Russian shell, but from the end of the month no forgings were obtained for many weeks, while early in December, 1917, work was hindered by air raids, which also did some damage to the factory. In February, 1918, there was a good increase, and production of 6-in. chemical shell was begun ; 840 6-in. proof shot were also bonded by the end of the month, and at the beginning of March the weekly output was 13,092 6-in. H.E., 252 cast-iron chemical shell and 48 proof shot. Instructions were then given to change over 5,000 6-in. H.E. to steel chemical, so that by April a typical week's output was 16,870 shells (6-in. H.E. steel chemical and cast-iron chemical) and 1,200 proof shot. In July, 1918, the factory was also rectifying proof shell and rebanding 6-in. C.P.C. The total output of 6-in. H.E. and chemical was 1,381,700.

In spite of the excellent labour-field to hand in North-East London, the Hackney factory experienced constant labour trouble ; 300 skilled and 2,700 unskilled men were required, but no provision was made at first for the employment of women. Labour for construction was obtained with difficulty, owing to the restriction of wages to the local rate of $11\frac{3}{4}$d. per hour, while the Ponder's End factory was paying 1s. 3d., and when production began the factory required a much more skilled class of men than that supplied through the Labour Exchange. Female labour was introduced, and in June, 1916, the Ministry recommended its extension in spite of the firm's opposition. In July and August, 1916, various disputes and partial strikes occurred, and in May, 1917, Hackney was affected by the shop-stewards' strike throughout the country. In October, 1917, slackness among the workers caused a drop in output, while in January, 1918, it was reported that the decreased production on night-shifts was due to the fact that women had to stand in food queues during the day. In June, 1918, the influenza epidemic greatly reduced the output, and the dispersal of labour began on 22 November, 1918. The numbers employed in October, 1918, were 4,473, of whom 1,431 (32·5 per cent.) were women.

The capital expenditure by March, 1918, was £652,600.

Lancaster National Projectile Factory (Messrs. Vickers).[1]

On 12 August, 1915, Messrs. Vickers Ltd., completed the purchase of a very suitable site for the proposed Projectile Factory at Lancaster, and forwarded details of the building and equipment required. The land selected covered about 33 acres, lying between one of the main roads of Lancaster and the River Lune. The London and North-Western Railway Company's canal, which formed the northern boundary,

[1] Hist. Rec./H/1122.4/1.

afforded facilities for the cheap transport of coal, the same company's line passed only a short distance away, while the Midland Railway crossed the site. A good water supply was drawn from the river. The scheme followed the general lines of the agreement for National Projectile Factories, and was considerably cheaper than any others proposed. Construction estimates were very moderate owing to the satisfactory nature of the site, the ease with which materials could be conveyed and handled, and the fact that buildings were only on one floor. By 11 September the necessary preliminaries to construction were begun, but as work was repeatedly delayed by various difficulties, erection and equipment were not completed till November, 1916.

The management of the factory was at first far from satisfactory. Many changes were made in subordinate positions on the staff without effecting any great improvement, and in December, 1916, when the Ministry instituted a thorough investigation into the working of the factory, it was reported that a most undesirable state of affairs existed. Tool arrangements were inadequate, untidiness and confusion prevailed in the shops, and machinery was not being used to the best advantage ; above all, a general slackness and lack of co-operation among the staff prevented real efficiency. In January, 1917, however, a new general manager was appointed, who succeeded in establishing far more satisfactory conditions. Difficulties also arose between the Ministry and Messrs. Vickers over the placing of orders for materials, components or machinery, and delays frequently occurred until October, 1916, when the Ministry issued new and definite instructions, leaving certain orders only to the discretion of the management.

The intended productive capacity of the factory was 3,500 9·2-in. H.E. shells, 6,000 6-in. H.E. shells and 6,000 60-pdr. shrapnel a week. The manufacture of shell began on 9 March, 1916, and by the end of the month 31·5 per cent. of the machinery was running, though the whole factory was not completed till the following November. In May, 1916, the first 60-pdr. shells were delivered, and in September the maximum output of 3,500 9·2-in. was reached. The 6-in. shops were behindhand, as it had been originally intended to erect them at Sheffield, but they began work in July, and in December, 1916, a change from loose head shell to bottled shell was effected. Shortage of materials and components caused serious difficulties till the end of 1916, when the completion of neighbouring plant for components rendered the locality self-contained. Early difficulties in obtaining sufficient gas from the Lancaster Corporation were overcome in 1917. A scheme for extending the factory, brought forward in January of that year, was eventually dropped.

In July, 1917, the factory undertook to manufacture 50,000 grenade mortars, in addition to their shell programme, and in September shell plant was transferred to Lancaster from the Sheffield (Hadfield's) and Nottingham factories then discontinuing shell production. Lancaster, which had formerly been doing some gun repair work, now stopped this, and from the spring of 1918 concentrated chiefly on 6-in. shell. Working conditions were disorganised by the fire at Morecambe Filling Factory on 2 and 3 October, 1917, and labour was drawn off for

salvage work. Output increased steadily throughout the spring of 1918, but was much hampered from May to July by changes in programme and by the influenza epidemic, which incapacitated about 20 per cent. of the workers. A recovery set in by the end of July, and the estimated maximum was exceeded in September. Altogether 993,900 6-in. shells (H.E. and chemical) were produced, in addition to 448,000 9·2-in., 9,600 8-in. and 589,500 60-pdr. shrapnel, making a total shell output of over 2,000,000. Work continued till the end of November, 1918, after which the employees were gradually discharged, but the factory turned over to the manufacture of aircraft bombs, which was in full swing in January, 1919; an allocation of 3,000 250 lbs. bombs was subsequently undertaken, and was completed together with 1,373 550 lbs. bombs in the following July.

The labour requirements for the factory were greatly underestimated at first, and a constant shortage prevailed. Women were employed from the beginning, but the factory suffered from lack of skilled men. By September, 1916, 4,819 men and women were employed, and in February 195 boys were added. In October, 1918, there were 8,656 employees, 47·3 per cent. being women. Some difficulties arose over the hours of women employees, and relations between the women and the management were at first unsatisfactory. No troubles arose, however, over the discharges at the end of 1918.

Though the construction estimates had been cheap, the actual capital expenditure of the factory was the largest of all National Projectile Factories, the total in March, 1918, being £1,580,200.

Nottingham National Projectile or Ordnance Factory (Messrs. Cammel, Laird).[1]

In August, 1915, the Nottingham Corporation offered the Government the free use of about 14 acres of land, between the Midland Railway and the King's Field Road, as a site for the proposed National Projectile Factory. The Corporation leased the land from private owners for £300 per annum, for the duration of the war and six months afterwards, and the lease was extended for a further period of one year, for which the Ministry was to pay rent. Before the completion of the buildings it was also found necessary for the Ministry to obtain the temporary use of an adjoining plot of land belonging to the Midland Railway Company. Possession was, therefore, taken under the Defence of the Realm Act, for the period of the war.

Construction of the buildings and railway sidings began in September, and good progress was made, power being temporarily supplied by the Corporation and Railway Company. Messrs. Cammell, Laird & Company Ltd., undertook to manage the factory for the production of 2,000 9·2-in. and 6,000 6-in. shells weekly, and refused to accept any fee for supervising erection or for management. Production began early in March, 1916, and was going well by April, though the forging shops were in advance of the machinery shops. By 22 July, 1916, the

[1] 94/Nat./141, 61, 113, 37; M.C. 16; (Printed) *Weekly Report, passim*; C.G.M. 387/3.

rated output of 9·2-in. shell was reached, and in September was exceeded by 50 per cent. The 6-in. output reached the promised maximum in October, 1916, and in January, 1917, the factory's capacity was re-estimated as 3,500 9·2-in. shells and 8,000 6-in. This programme was carried out immediately, and the 6-in. output reached nearly 10,000 by March, 1917, but from April to June of that year part of the plant was changed over to the manufacture of Italian (149 mm.) shell. From July, 1917, the 6-in. output again rose rapidly to over 13,000 weekly.

In March, 1917, as part of the general reorganisation of shell capacity, the factory began to repair 18-pdr. guns, and shortly afterwards undertook manufacture of the same gun, in addition to the shell programme. In the autumn it was decided that Nottingham should be used for gun work only, and that the shell plant should be gradually transferred to Lancaster. The factory was, therefore, classed thenceforward as a National Ordnance Factory. The production of 9·2-in. shell ceased at the end of October, 1917, but two units of the 6-in. shops remained at work through the spring of 1918, to avoid dislocation of labour during the period of setting up gun machinery. Shell production, however, had completely ceased by June, 1918, by which date the total output of 6-in. amounted to 684,300 and of 9·2-in. to 210,100.

The gun plant was originally laid out for 20 18-pdrs. (new or repaired) a week, and the total number of this type produced was 354 new and 585 repaired guns. At the end of 1917, instructions were received to turn over to the new 6-in. Mark XIX gun, and capacity for 120 guns a month was provided. The first 6-in. gun was produced in June, 1918, and by the end of October 112 had been made. Repairs of this type and of the 9·2-in. were also undertaken.

In September, 1915, Messrs. Cammell, Laird proposed to employ 1,230 women in the 6-in. shell shops, but considered it impossible for them to handle the heavier shell. The number of men required on both natures of shell was 2,538, 287 of whom were skilled. By June, 1916, 3,056 men and women were already employed, and there was a very large demand for additional labour. By the beginning of 1917 the numbers had risen to 5,835 about half (53·8 per cent.) being women.

The contract price for the buildings alone was £100,500, and the total capital expenditure by March, 1918, was £796,500.

Renfrew National Projectile Factory (Messrs. Babcock & Wilcox).[1]

As a result of the development of the Glasgow Shell Scheme[2] in August, 1915, Messrs. Babcock and Wilcox undertook to erect and manage two factories, the Ypres Factory for the production of 12-in. H.E. shell and the Aisne Factory for machining 60-pdr. shrapnel.

Ypres.—The site for the Ypres factory, covering about 6 acres next to the firm's works and connected to the same railway line as the shrapnel factory, was bought under three separate conveyances. Construction was very slow and production did not begin till late in

[1] 94/Nat./60, 66, 49, 110 ; D.D.G.(A.) 3190 ; (Printed) *Weekly Report, passim.*
[2] Vol. II, Part II, Chap. XIII.

the summer, the first delivery being in August, 1916. The factory undertook to produce 500 12-in. shell weekly, and by December, 1916, the average output was 438, while the maximum was reached by 13 January, 1917. In this month a change over was made from 12-in. to 9·2-in., of which 1,200 weekly were promised. After some early difficulties as to forging, the output of the new nature rose steadily but slowly to an average of 1,000 in August, 1917, and in November following this figure was accepted as the maximum capacity of the factory. The numbers employed at this date were 610, only 18·4 per cent. being women. In 1918, the output of shell was considerably reduced, and in the autumn of 1918 it was proposed to change over the 9·2-in. plant again to the production of 12-in., H.E. shell; but though the output of the former fell rapidly in September and October, 1918, no 12-in. shell were delivered before the Armistice. The factory's total output of 12-in. was 6,100 and of 9·2-in. 64,300. The employees in October, 1918, numbered 490, of whom about half (49·4 per cent.) were women.

Aisne.—For the shrapnel shell factory, Messrs. Babcock and Wilcox offered the Government about 10 acres, also adjoining their own works, but not immediately next the Ypres factory, at £258 10s. 0d. a year. An agreement was drawn up on the usual lines, and the firm were to have the option of buying the factory, with or without the plant, when it was no longer required by the Ministry. Construction was started in November, two or three months after most of the English National Projectile Factories, and, as in the neighbouring Ypres factory, progress was very slow, being frequently delayed by bad weather. The factory was laid out to machine 10,000 60-pdr. shrapnel shells a week, forgings being supplied under direct contract from the managing firm, who extended their existing plant at their own cost, in return for the Government's guarantee that all orders for forgings for the Aisne factory should be placed with them. Production was started by 27 May, 1916, well ahead of the 12-in. factory, but no shell were delivered until July, 1916. The output rose very slowly, only averaging 1,780 in August, 1916, while throughout 1917, it was seldom more than 5,000 weekly. In December, 1917, production was much hampered by lack of components but in 1918 a great improvement was effected, and by April, 1918, the output was above the programme, remaining at about 11,000 weekly after August, 1918. The total output to the end of 1918 was 645,700.

The chief labour difficulty at Renfrew occurred during the changes from the one nature of shell to the other, which were hampered by lack of skilled labour. Women were largely employed in the Aisne factory, the total staff required being estimated in March, 1916, as 60 skilled men and 700 women. In October, 1918, women were 80·7 per cent. of the total number (1,690). Night-shifts were started in June, 1918, and gave very good results. In 1916, only male labour was employed in the 12-in. factory, 25 out of the total 375 being skilled men.

Early in 1917 the estimated capital expenditure on the Ypres and Aisne factories was revised, as £154,927 and £119,026 respectively. By March, 1918, the actual expenditure was £165,900 and £114

Sheffield National Projectile Factory (Messrs. Firth).[1]

In September, 1915, an agreement was concluded with Messrs. Firth and with Earl Fitzwilliam for the site for a National Projectile Factory at Sheffield. Machine-shops were to be built on an area of about 13 acres at Templeborough, on the Sheffield-Rotherham road, rented from the Earl on a 21 years' lease. Railway facilities were good when once a siding had been constructed, and power was obtainable from the Sheffield and Rotherham Corporations. Messrs. Firth, of Sheffield, undertook to erect and equip the factory here along the lines laid down by the standard agreements for National Projectile Factories. The forging shop was erected on about $3\frac{3}{4}$ acres rented from Messrs. Firth, and adjacent to their own works at Tinsley. Owing to the peculiar position of the forging-shop, and particularly the difficulty of distinguishing between labour and power there and in the firm's own workshops, distinct provisions were made whereby the forging-plant was erected at government cost, but the managers ran the Tinsley shops at their own expense and with their own labour, receiving a fixed price for forgings, and in consequence a lower price for the completed shell at Templeborough. Extensions were made at State cost to the power plant at Messrs. Firth's own factory, the capital expenditure being repayable after the war. The firm agreed to produce at the new Tinsley shops forgings to be machined at the Templeborough National Projectile Factory, until the latter ceased work, or Government orders should fall below half the plant's capacity for three months When this occurred the firm were to have the option of buying any or all of the plant; otherwise the Government would be entitled, but not bound, to remove the buildings and machinery.

Constructional work began in September and proceeded so rapidly, in spite of difficulties as to labour and plant, that shell-turning began on 19 January, well ahead of any other National Projectile Factory. The ultimate output was estimated at 21,000 60-pdr. H.E. shell, and by the end of May, 1916, the weekly output reached 2,000. In January, 1917, the maximum was raised to 27,500 60-pdr. H.E. and in March an addition of 30,000 4·5-in. H.E. shells per week was made. In May, 1916, the factory began making 8,000 60-pdr. S.K. shells in place of that number of 60-pdr. H.E. None of the new type of shell was actually delivered until mid-November, 1916, after considerable difficulties arising out of the processes involved, and the factory ceased to produce them early in 1917, though in December following a consignment of 4·5-in. chemical shell was bonded. Production of the 4·5-in. H.E. shell ceased in July, 1918, when the factory concentrated on producing 60-pdr. H.E., the maximum output of which was not reached, and a small quantity of 4·5-in. chemical shell. The total output of 60-pdr. H.E. and chemical shell was 1,842,800, and of 4·5-in. 766,300.

The labour requirements for the factory had been estimated in 1915 at 300 skilled men, 1,000 unskilled and 4,000 women. Twenty women were trained on the machines as soon as shell-turning began,

[1] 94/Nat./45, 46, 53, 57, 100, 135, 147, 150; (Printed) *Weekly Report, passim*; HIST. REC./H/1122.4/9.

and the large percentage of women employed and trained in the factory gave excellent results. Nevertheless, difficulties in obtaining labour were frequent, although special training schools were inaugurated. In October, 1918, when there were 5,693 employees (women 87·2 per cent.), losses were reckoned at 50 weekly, and substantial improvement in output was prevented by lack of skilled labour. From 25 November, 1918, short time was worked, and the workers were gradually discharged without trouble.

The outstanding features noticeable in this factory were the effects of the establishment of two National Projectile Factories in such close proximity as Messrs. Firth's and Messrs. Hadfield's, and the close co-ordination between the new factory and Messrs. Firth's private works. Both these facts eventually proved advantageous, for central ministerial organisation solved the obvious difficulties as to local supplies of labour and materials, and the two National Projectile Factories were able to help each other in emergencies. Messrs. Firth's factory was also of great assistance, particularly in providing skilled men for purposes of "speeding-up," affording temporary supplies of urgently needed components, or undertaking necessary processes during changes of programme.

The capital expenditure had been estimated in July, 1915, at £800,000, but by March, 1918, the actual expenditure was only £661,800.

Sheffield National Projectile or Ordnance Factory (Messrs. Hadfield).[1]

In September, 1915, clearing operations began on a site selected for this National Projectile Factory, while the Ministry entered into prolonged negotiations with Messrs. Hadfield as to the rental for a lease of 21 years. The land covered about 14¾ acres, adjacent to the firm's own works; power, water and gas were readily obtainable from the Corporation, and by laying a short length of track good railway facilities with the Great Central and Sheffield District railways were secured. The site was near that of Messrs. Firth's National Projectile Factory,[2] and, later, the firm occasionally undertook urgent work for the Templeborough factory.

Two agreements for erection and equipment and for management, drawn up on the lines common to all National Projectile Factories, were made with Messrs. Hadfield. Constructional work began late in September, 1915, and after a rather slack period in December, proceeded quickly through January, 1916. By February the building was more advanced than any other National Projectile Factory still in construction, and was completed in the next month.

The factory was laid out to produce 4,000 9·2-in. H.E. shells weekly. Shell-turning began during the week ending 25 March, 1916, and by 13 May 1,500 shells were delivered in fulfilment of promises. A gradual

[1] 94/National/73, 150, 136; D.M.A./Advances/904; C.R.V./S./42; M.C. 16; C.G.M. 387/2; (Printed) *Weekly Report, passim.*

[2] *See* above, p. 145.

increase in output continued for three months, the estimated weekly output being exceeded in August, 1916; it was maintained, in spite of some difficulties as to steel supplies, until March, 1917, the weekly output in January of that year reaching more than 5,000. The restricted shell programme of the spring of 1917 reduced production in this factory, and in May the output dropped to an average of 1,572 weekly, remaining about 2,600 till October, 1917, while the factory undertook gun-repairing at the rate of 60 60-pdrs. a month. To avoid the dual control necessitated in factories engaged in both gun and shell production, a general reorganisation was planned in September, 1917, and Messrs. Hadfield's factory changed over entirely to gun-repair, half the shell plant being exchanged for gun machinery from Lancaster, and half transferred to St Helens. By 9 February, 1918, the shell output had ceased, a total of 289,200 having been reached, and the factory undertook to repair 90 60-pdr. guns per month. Later, the manufacture of new 60-pdrs. was also undertaken, and the factory became a National Ordnance Factory, being administered by the Gun Manufacture Department.

In August, 1918, a serious shortage of coal occurred, but good progress was made on a new design of 60-pdr. gun, which was delivered to proof early in the month. The gun work undertaken included the rifling of 60-pdrs. and 8-in. from other factories. During November, 1918, the factory also bonded about 120 6-in. howitzer proof-shot weekly.

In August, 1915, the labour requirements had been estimated as 1,200 males, and in December following this was raised to 450 skilled and 1,750 unskilled men. By May, 1916, 647 men were employed and night-shifts were started, but though the labour steadily increased, no women were employed. In May, 1917, the engineers' strike reduced the production of forgings, while in June, 1918, labour difficulties again arose on the removal of men up to 20 years of age. The numbers employed at the beginning of 1917, before the factory turned over to gun work, were 2,465, and in October, 1918, 1,274.

The financial arrangements with Messrs. Hadfield were the subject of prolonged negotiation. The estimates for capital expenditure were £500,000, and the rent asked for the site was at first more than three times that considered reasonable at headquarters, while the amounts charged for providing tools and on various other accounts, gave rise to dispute in September, 1916. The actual capital expenditure by March, 1918, was £487,800.

CHAPTER V.

NATIONAL FILLING FACTORIES.

I. Introduction.[1]

The National Filling Factories were divided into three classes: those dealing with (*a*) gun ammunition, including shell, cartridges and minor components; (*b*) trench warfare ammunition, including bombs and grenades with their fuses; and (*c*) chemical shell. The largest of these classes was that for filling gun ammunition and this will be dealt with first.

(*a*) *Gun Ammunition Filling Factories.*[2]

In normal times the whole of the supplies of gun ammunition for the Navy and Army and most of the components used with it were filled or assembled at the Royal Laboratory, Woolwich. At the outbreak of the war shell filling capacity in the trade was limited to five firms, one of which had filled shell with lyddite during the South African War, while the others had from time to time supplied filled ammunition to foreign countries. One of these had filled certain experimental shell for the British Government. Greater trade capacity existed for filling fuses and minor components, but no shell-filling of any kind was undertaken by the trade until early in 1915.

In July, 1915, a conference of the various armament firms was summoned by the Ministry to discuss the means of meeting the heavy increase in the shell programme needed to supply the requirements of the army. At this meeting a definite proposal was made to build National Projectile Factories.[3] This plan was subsequently adopted as the best method of meeting the situation. The increased supply of shell which this decision implied involved an immediate increase in the filling capacity, especially as it was already becoming evident that the existing facilities for filling were not sufficient to meet the growing production of empty shell from the trade, the local groups and the National Shell Factories, nor to cope with unexpected deliveries of incomplete rounds from American and Canadian contractors. It was, therefore, decided that increased capacity should be provided by the establishment of National Filling Factories.

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[1] Hist. Rec./H/1340/1, 1520/8, 1600/9, 1122/4, 5, 6, 7, 8, 11, 30, 31, 32, 33, 35, 43, 44, 45, 46, 47; Hist. Rec./R/1320/10; 1122.3/44, 45, 46; 400/57; M.C.372; C.R./Filling/22; T.W.D./219/2.

[2] For the place taken by these factories in the general arrangements for filling, *see* also Vol. X, Part V.

[3] *See* above, p. 124.

From the point of view of work, the National Filling Factories were divided into three classes. It was intended in the summer of 1915, to establish four factories, at Leeds, at Liverpool, in Scotland (Georgetown) and at Gloucester, for filling and assembling Q.F. ammunition, either shrapnel or high explosive, and making up B.L. cartridges. Five distinct factories, at Chilwell, Morecambe, Banbury, Newburn and Otley were to be engaged entirely upon the more dangerous operation of filling heavy high explosive shell. Six factories, at Coventry, Perivale, Southwark, Hayes, Abbey Wood and Cardonald, were intended to assemble and fill various classes of gun ammunition components.

From the point of view of administration, these factories were of three types; (1) administered directly under the Ministry by a factory manager, as in the case of Chilwell, Hayes, Southwark, Banbury, and later Hereford and Gainsborough; (2) controlled by agents for the Ministry, as at Coventry, Abbey Wood, Cardonald, Morecambe and later, Pembrey; and (3) administered by local Boards of Management, as at Leeds, Liverpool, Georgetown, Gloucester and (temporarily) Perivale. These Boards were appointed by the Minister. Their members acted without remuneration or profit. They were responsible both for the erection and the operation of the Filling Factories in their district.[1] Although their establishment was a part of the general scheme of 1915 for utilizing local resources, they reported direct to the Gun Ammunition Filling authority and not to the Director of Area Organisation as the National Shell Factories did.[2] At their inception in 1915, the Boards were given entire responsibility for the internal administration of their factories. By November, 1917, individual members only of three out of the five Boards of Management continued in anything more than an advisory capacity. The fourth factory at Perivale had been taken under direct control by the Ministry in June, 1916. In the fifth, at Leeds, members of the Board retained so complete a control over the internal administration of the cartridge-filling and amatol factories, that the authority of the Gun Ammunition Filling Department was difficult to maintain in matters touching technique, finance and accounting, particularly costing, and in the provision of means for ensuring safety and the health and welfare of operatives. Uniformity in these respects was becoming more and more essential as the financial position and material resources of the country became more stringent, and as the Ministry's responsibility for safety conditions within the Government factories became more clearly defined. It was accordingly proposed in November, 1917, to take all the filling factories from Boards of Management and place them under direct control. The project was, however, abandoned in face of strong local opposition at Leeds to the abolition of a body which had so successfully constructed and equipped the filling factories, and had maintained so large an output.[3]

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[1] A.M.4/Circulars No. 4 (copy in HIST. REC./R/201).
[2] *See* above, p. 89.
[3] G.A.F. 3622; M.C. 485.

For guidance in determining the lay-out of the four Q.F. ammunition filling factories at Leeds, Liverpool, Georgetown and Gloucester, certain general principles were laid down in accordance with those which experience in constructing the same kind of building at Woolwich had shown to be desirable, while the general regulations of the Home Office regarding buildings in which explosives were handled, were also adhered to as far as conditions allowed, but with the time and space available it was admitted that it was impossible to keep strictly to this, for example, in the matter of spacing. Beyond this, full latitude was given to the architect, a member of a London firm. In most cases construction was carried out by a local firm of builders. The lay-outs of the factories at Coventry and Perivale were undertaken by an architect who had designed a somewhat similar factory at Luton. At Coventry, the building was in the hands of a firm in the neighbourhood, while the Office of Works was responsible at Perivale. At four of the factories controlled by managing directors, viz., Chilwell, Hayes, Southwark, and Banbury, the buildings were designed by the managing directors, who, in the case of Chilwell and Hayes, chose London firms to carry out the construction. Banbury was built by the Office of Works, while at Southwark the buildings required in place of those already on the site were practically supplied by the use of wooden sheds obtained in sections ready for erection. The factories which were built at Hereford and Gainsborough at a considerably later date were designed and built by the Office of Works. The lay-out and construction of the agency factories at Abbey Wood, Cardonald, Pembrey and Morecambe, were left to the contractors responsible for their administration. In the case of the factories administered by Boards of Management and by agents, where the Office of Works was not directly responsible for the construction, a member of the construction staff of that Department was appointed to co-operate with and assist the builders.

Work at the filling factories was marked by two characteristics: it was unskilled, and it was all, to a greater or less degree, according to the nature of the work, dangerous. While the first of the characteristics widened the field from which labour could be drawn beyond the limits set by the requirements of the more highly skilled engineering processes, the second confined the choice of workers to the most accurate and conscientious procurable. Work which involves the continual handling of explosive materials cannot fail to be dangerous, and no regulations, however carefully made, can do more than mitigate this danger. It can, however, be greatly enhanced by failure to carry out the regulations, by careless work, or by impatient or stupid action in an emergency. Nevertheless, daily contact with even the most dangerous substances must result in dulling the sense of risk, and it was therefore essential that, in taking on workers, only the steadiest and most careful should be selected. In the early days of the war, the workers were exposed to an additional danger from lack of knowledge as to T.N.T. poisoning. At that time little was known of the effect on the health of the constant handling of T.N.T., but immediately after the first death officially reported as due to T.N.T. poisoning the Home Office

took steps to circulate information and instructions to the medical officers at factories handling T.N.T. At the same time investigations were instituted into the causes and means of prevention of the poisoning. By January, 1918, the percentage of operatives suspended for T.N.T. sickness at the largest National Filling Factory had been reduced from 11 in August, 1916, to 1.[1]

Generally speaking, little difficulty was experienced in obtaining the large numbers of unskilled workers which were needed for these factories. Such shortage as did occur was usually attributable to extraneous circumstances, such as a deficiency of housing accommodation or great local competition for labour, as was the case at Perivale. The numbers employed in all the factories working in March, 1917, were about 82,000, of whom 81 per cent. were women. In the autumn of 1918, the employees totalled 72,000, and the percentage of women was 75.[2]

The first of the National Filling Factories to come into operation with the exception of the emergency unit at Southwark, which was filling gaines early in September, 1915, was Hayes, which began output on 30 October, 1915,[3] while Perivale followed on 1 December. Bad weather conditions and the shortage of labour held up construction at several of the factories, but by March 1916, practically all were engaged on production. At Coventry, which began output in March, further delay was caused by uncertainty as to the type of buildings and machinery to be erected, and by difficulties with regard to the railway sidings. The site for the lyddite factory at Banbury was not decided upon until December, 1915; construction began at the end of January, 1916, and output on 25 April.

During the autumn and winter of 1915–16, the treatment of amatol was more or less in the experimental stage, and the consequent uncertainty as to the plant required was partly responsible for considerable delay in erecting and starting up the factories for filling heavier natures. The whole scheme for these factories was revised in February, 1916. Otley and Newburn, where scarcely any progress had been made, and to which the filling of Q.F., instead of B.L., ammunition had been assigned, were then abandoned. Their work was transferred to new amatol factories, which were erected alongside the Q.F. ammunition factories at Leeds, Liverpool and Georgetown, and were placed under the same management as those factories.

Hereford was a later project; building there did not begin until July, 1916; and the first shell were filled in November. Hereford was the last of the new shell-filling factories to be erected and was intended as a stand-by factory. Minor filling projects materialised at later dates. The factory at Gainsborough, which was established

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[1] For a full account of the measures taken *see* Vol. V, Part III, Chap. IV.

[2] The same figures (total 7,452; women 1,730) have been taken for Chilwell in each case, as no figures later than March, 1917, are available.

[3] Pembrey, which began work on 2 July, 1915, did not become a national factory until January, 1917.

at the request of the Admiralty for filling mines and sinkers, was begun in November, 1917, and began work in February, 1918. The Luton fuse-filling factory was erected during the winter of 1916–17.

A great part of the achievements of these factories consisted in the working out of new filling methods and the improvement of established methods. The mixture of ammonium nitrate and T.N.T., known as amatol, was introduced as the result of experiments by Research Department, Woolwich, about April, 1915. It was first used in the national factories in the form of block charges of 80/20 amatol, which were prepared by milling at a contractor's factory and sent to the Ordnance Factory, Woolwich, and the Q.F. ammunition factories to be put into shell. Originally it was intended that the factories which were to fill the heavier natures of shell should also employ this method, but comparative trials with some of the larger shell showed that this form of filling produced results inferior to those from direct filling into the shells by the French method. It was, therefore, decided to confine block-filling to 18-pdr. shell only and equip the factories which were to fill shell of higher calibre with plant for direct filling. The simplest method of this form of filling was melt filling with 40/60 amatol, which did not require any elaborate plant. The necessity of economy in the consumption of T.N.T., however, rendered imperative the use of a mixture with a smaller proportion of this explosive, and, as an increased proportion of ammonium nitrate rendered melt-filling impossible, it was necessary to instal pressing plant for filling the larger natures of shell. It was foreseen, however, that considerable delay must occur before the large amount of machinery required could be supplied, and, in view of the urgent demand for shell, it was decided to instal melt plant in the new units at Leeds, Liverpool and Georgetown for use until the pressing plant was ready. The lay-out at Chilwell, which was planned by Lord Chetwynd, provided from the first for pressing as well as melt filling direct into the shell, and this factory was the first to use the former method.

In July, 1916, experiments were made at Georgetown in hot-filling with amatol 80/20. The process was approved in December, 1916, and was adopted there and at other factories with melt plant, except the Ordnance Factory, Woolwich, as a general method of adapting the melt-plant buildings to fill 80/20, instead of 40/60 or 50/50 amatol.

A firing trial with shell filled at Morecambe by screw stemming was carried out in November, 1916, and further experimental work on these lines was then transferred to Liverpool. In the spring of 1917, these machines were introduced for practical purposes both at Chilwell and Liverpool. Screw-filling with hot amatol was tried in January, 1917, with a vertical machine, but by June of the same year a horizontal machine had been proved to give better results, and was substituted for the vertical one.

Shell filled with 80/20 at first gave results inferior either to those filled with 40/60 or lyddite, and much time and thought were expended on improving the quality of detonation. The following comparative

table of the results at proof in September, 1916, and September, 1917, shews the improvement achieved.

Percentage of Detonations.

—	September, 1916.	September, 1917.
Lyddite	88	99
40/60 and 50/50 Amatol	92·5	98·5
80/20 Amatol	76	99

Contemporaneously with the development and improvement in methods of shell-filling, similar work was carried out with components. One of the most urgent problems in this connection was the improvement of the No. 100 type fuse and gaine. As a result of the unsatisfactory functioning of this fuse, and the big percentage of prematures which occurred with it in the autumn of 1916, large numbers were broken down, when it was found that in many cases vital parts, such as creep springs, detent springs and centrifugal bolts were missing, while the detonators were often dirty, inadequately filled, and not properly closed. Faults were also found in the filling of the gaine, in which, in many cases, the detonator was found to be upside down. To remedy this state of affairs, investigations were made into the methods employed at the various factories, as a result of which filling operations were standardised, and the standard of inspection appreciably raised. An important improvement of method in filling detonators was the introduction of varnishing and rumbling after filling, which was applied not only to the No. 100 type fuse detonator, but to all natures, and resulted, by the end of 1917, in a very high standard being reached. Throughout the existence of the National Filling Factories the efforts of the central department were concentrated on attaining, by means of a comparison of factory methods and the standardisation of operations, an increasingly high standard of efficiency. This was greatly assisted by the establishment, in 1917, of the Standard Production Unit at Perivale, where experiments were carried out under ideal conditions, the results of which were communicated to the factory managements.

In work which involved the yearly handling of thousands of tons of explosives it was inevitable that accidents should occur. Two explosions of a disastrous nature, as well as several less serious ones, marked the history of the filling factories. The first of these took place at Morecambe, where a fire which caused a series of explosions broke out on 1 October, 1917, and continued for nearly three days and nights, during which the factory was almost totally destroyed, though, fortunately, only ten lives were lost. On 1 July, 1918, an explosion occurred in the melt house at Chilwell, which, though it caused less material damage than the Morecambe fire, resulted in 134 deaths.[1]

[1] For fuller details, *see* HIST.REC./H./1122/43, 44.

The following table shows the yearly output of the principal natures of shell filled by the National Filling Factories during the war. The figures include the output of depôts at Devonport[1] and Horley[2] which completed foreign ammunition in 1915 and 1916, but not that of Pembrey, which was nationalised in January, 1917, and stopped shell filling in the succeeding May.[3] Details of the output of individual factories will be found in Appendix III.

Nature of Shell.	1915.	1916.	1917.	1918.	Total.
18-pdr. H.E.	10,600	6,830,700	13,238,000	11,886,300	31,965,600
18-pdr. S.	63,000	8,385,300	9,660,900	9,583,000	27,692,200
18-pdr. A.A. ..	—	—	4,600	300	4,900
13-pdr. H.E. ..	—	—	19,900	420,900	440,800
3-in. 20-cwt. H.E. ..	—	—	—	114,800	114,800
6-pdr. C.P.	—	—	—	225,600	225,600
60-pdr. H.E. ..	—	975,400	2,069,100	1,686,100	4,730,600
60-pdr. S.	—	200,400	519,500	771,200	1,491,100
4·7-in. H.E. ..	—	23,300	—	—	23,300
4·5-in. H.E. ..	—	4,539,200	9,432,800	7,231,100	21,203,100
4·5-in. S.	—	16,400	15,600	—	32,000
5-in. H.E.	—	—	125,600	—	125,600
6-in. Gun H.E. ..	—	—	27,200	227,700	254,900
,, S... ..	—	—	—	104,800	104,800
6-in. How. H.E. ..	—	2,178,500	10,295,400	12,108,500	24,582,400
8-in. How. H.E. ..	—	564,200	2,153,800	1,867,000	4,585,000
9·2-in. Gun H.E. ..	—	—	—	8,900	8,900
9·2-in. How. H.E. ..	—	706,400	1,565,000	1,029,900	3,301,300
12-in. How. H.E. ..	—	49,400	95,500	73,400	218,300
15-in. H.E.	—	1,100	5,900	5,100	12,100
Grand Total ..	73,600	24,470,300	49,228,800	47,344,600	121,117,300

As will be seen from the detailed accounts of the factories, this table does not by any means represent their entire output. Five or six of the factories undertook no shell, but only components, and some millions of the latter were also filled in factories dealing with shell. The following table shows the yearly output of fuses filled at the National Filling Factories during the war. The figures given denote thousands.

Type of Fuse.	Aug. 1914 to Dec. 1915	1916.	1917.	1918.	Total.
Percussion	—	16,905·6	33,438·9	27,314·6	77,659·1
Time and Percussion or Time.	9·9	—	1,722·4	393·9	2,126·2
Base	—	—	—	14·2	14·2
Total	9·9	16,905·6	35,161·3	27,722·7	79,799·5

[1] Completed 3,057,000 18-pdr. shrapnel from abroad.
[2] Completed 4,737,100 18-pdr. shrapnel from abroad.
[3] The total output of filled shell from Pembrey, including contract deliveries, was 1,143,000 8-in., 6-in., and 4·5-in.

At the beginning of 1918, the drastic reductions made in the shell programme left several of the factories with surplus capacity. Arrangements were therefore made to utilize these for filling trench warfare ammunition and aerial bombs and charging chemical shell. Perivale received allocations for filling trench mortar bomb fuses. Hereford took over all the 50 lb. aerial bombs and Chilwell the big S.N. aerial bombs filled with amatol 70/30. Gas charging and the assembling of gas shells were assigned to Banbury and Hereford. At the end of June, the possibility of utilizing the shell filling plant at Georgetown for filling trench mortar ammunition was under discussion, but the explosion at Chilwell put this out of the question, and the Trench Warfare Filling Factories continued to be responsible for all filling of trench warfare ammunition.

(*b*) *Trench Warfare Filling Factories.*[1]

Like the National Filling Factories, the Trench Warfare Filling Factories[2] were planned in the summer of 1915, to provide the increased filling capacity for trench mortar ammunition then demanded by the expansion of the War Office programme. They were originally three in number, situated close to the ammonal works from which they were to draw their supplies of filling material: (1) At Erith near the Thames Ammunition Works: (2) at Denaby, Yorks, adjacent to the works of the British Westfalite Company, and, (3) at Watford, on part of a site where the Explosives Supply Department was to erect a new ammonal factory. The capacity of the Erith factory was to provide for the filling of 20,000 2-in. bombs weekly, that of Denaby for 70,000 3-in. Stokes bombs, while the capacity of the Watford factory was the same as that of Erith. The principal buildings at all three factories were completed by February, 1916, but output began some time earlier; Erith filled its first 2-in. bombs on 9 October, 1915, Watford began a week later with 3-in. Stokes bombs, and turned over to 2-in. bombs in December, when Denaby came into operation. It was at first intended that the Watford works only should be a national factory, but it was subsequently found desirable to nationalise Denaby and Erith as well. Denaby was administered by the British Westfalite Company as agents at a fixed yearly fee and a bonus on output. Watford was directly administered by the Ministry, and in January, 1916, similar arrangements were made with regard to Erith. In February, 1916, the factory of the W.E. Blake Explosives Loading Company, at Fulham, which was engaged on loading ball grenades and 3-in. Stokes bombs was also nationalised. During this month the construction began of a second factory at Watford under the same management as the first. It was intended for filling heavy trench mortar bombs.

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[1] For the place taken by these factories in the general organisation for producing trench warfare stores, *see* Vol. XI, Part I.

[2] "National Filling Factories" was the title usually given to factories for filling gun ammunition, factories where trench warfare ammunition was filled being known as "Trench Warfare Filling Factories." The two groups are distinguished thus throughout this chapter.

Constant changes of programme, as well as the development of the functions of the Trench Warfare Department of the Ministry brought corresponding modifications of the work carried out at these filling factories.

In February, 1916, the Watford factories undertook the assembling of fuses for trench mortar bombs. In May, the assembling of filled 336 lb. aerial bombs was allocated to Watford No. 2, and in September the filling of 112 lb. aerial bombs with amatol began there, and from that time onward was an important feature in the work of the factory.

During the first years of the war, trench mortar ammunition was filled with ammonal, but between January and May, 1917, this was gradually replaced by 80/20 amatol. In contrast to the method followed at the National Filling Factories, which mixed their own amatol, the amatol for trench mortar ammunition was received ready mixed at the filling factory. This prevented the adoption of hot-filling, which would have involved mixing on the spot, but as such a change would have necessitated the entire reorganisation of the factories, the idea, which had been entertained during the first four months of 1917, was abandoned in May. Machine filling, which, from the spring of 1917, was being increasingly adopted in the National Filling Factories, was not generally practicable in the Trench Warfare Filling Factories, with the exception of small time and labour-saving apparatus, owing to continual changes in design and type of the ammunition to be filled.

In May, 1918, the control of the Trench Warfare Filling Factories was transferred to the Controller of Gun Ammunition Filling and, as recorded above, part of their work in filling aerial bombs was distributed among the National Filling Factories. Proposals had already been made for relieving them of some of the filling of trench mortar bombs when the explosion at Chilwell not only made this impossible but necessitated the return of all aerial bomb-filling, with the exception of the heavy bombs filled in the melt houses at Chilwell, to the trench warfare factories. Shortly before the Armistice, however, arrangements were made for filling 6-in. trench mortar ammunition at the National Filling Factories.

In the autumn of 1918, the numbers employed at Erith, Denaby, Fulham and the two Watford factories were approximately 3,000, and of these 83 per cent. were women.

(c) *National Factories for Filling and Assembling Chemical Shell.*[1]

The completion of chemical shell by "filling," *i.e.*, by inserting the bursting-charge and by "assembling" with the fuse and cartridge was carried out partly at national factories erected or taken over for the purpose, partly at Trench Warfare Filling Factories and also, in 1918, at some of the National Filling Factories. Before June, 1916, both the filling and assembling of grenades, and later of lachrymatory shell had been carried out at a contractor's factory at Walthamstow, where the lachrymatory liquid was also charged into the projectile. This factory

[1] For the part played by these factories in the production of chemical warfare stores, *see* also Vol. XI, Part II, Chap. III.

lay in a very congested neighbourhood and in June, 1916, it was nationalised and decision was taken not to use it for the purpose of assembling lethal shell.[1] This work was temporarily undertaken at the Ordnance Factory, Woolwich. The assembling of 4-in. Stokes mortar bombs, and the filling of the gaine with ophorite was allocated to the Trench Warfare Filling Factory, Watford, No. 1. From this time (July, 1916) onwards, an increasing proportion of the capacity of this factory was devoted to the assembling of chemical bombs, while, in April, 1917, Watford, No. 2 received a weekly allocation to assemble 20,000 chemical shell. In August, 1916, the construction of a national chemical shell assembling factory was begun at Greenford in order to relieve the Ordnance Factory, Woolwich, from the dangers of leaking shells.

New arrangements were made in connection with the assembling of shells charged with mustard gas. In November, 1917, an agreement was completed with Nobel's Explosives Company Ltd., for the erection and administration of a factory for making mustard gas (H.S.) as well as for charging and filling the shell. A site was selected at Chittening and construction began in January, 1918. In the spring, owing partly to the increased production of H.S. required, it was decided to place the manufacture and the charging into shell under different authorities. The control of the charging and completion of these shells was placed in the hands of the Controller of Gun Ammunition Filling and Chittening was accordingly transferred to his department. Experimental charging began at the end of June, 1918, and by 14 July 1,000 6-in. shells had been charged. The work at Chittening was of a particularly dangerous and unpleasant nature and at one time the casualties amounted to nearly 100 per cent.

The work done by these factories and by the National Filling Factories in head-filling and assembling chemical, incendiary and smoke shell is shown in the following table.

Nature of Shell.	1916	1917	1918	Total
18-pdr. Chemical	—	—	251,600	251,600
18-pdr. Incendiary	—	—	39,000	39,000
60-pdr. Chemical	—	580,900	63,800	644,700
4·5-in. Chemical	18,000	954,700	1,230,700	2,203,400
,, Smoke	—	118,500	349,200	467,700
6-in. How. Chemical	—	49,800	1,309,000	1,358,800
Total ..	18,000	1,703,900	3,243,300	4,965,200

The gross capital expenditure to 31 March, 1918, on the National Filling Factories amounted to £10,295,000, on the Trench Warfare Filling Factories to £215,800. These figures exclude the cost of the later work entailed by converting plant at the National Filling Factories for

[1] For the account of Walthamstow, *see* below p. 184.

chemical work. The cost of Greenford and Walthamstow factories, engaged from the first on filling and assembling chemical projectiles, was £118,000 up to the end of March, 1918. The H.S. Filling Factory at Chittening was not then complete, but Treasury sanction had been received for an expenditure of £750,000. The actual cost of Chittening by March, 1919, was £57,900.

II. Individual National Filling Factories.

National Filling Factory No. 11, *Abbey Wood.*[1]

In accordance with a scheme for the erection of filling factories for minor components in the London area, the Ministry, in the middle of August, 1915, opened negotiations with the King's Norton Metal Company, a firm which had had many years experience in work of this nature.

A convenient site was selected on the company's property adjacent to their works at Abbey Wood, and construction began on 23 September, 1915. A part of the land was taken under the Defence of the Realm Act, and part by agreement with the company.

The building agreement between the Ministry and the company provided for the erection of the factory by the company on their own land at the Ministry's expense, with an additional sum paid to the company to cover equipment, establishment charges, and a fee for supervision and profit. A representative of the Office of Works was appointed to superintend and assist in the work. Under the agreement for administration, the factory was to be controlled by the company acting as agents of the Ministry on the basis of a lump annual sum, not contingent on output.

The original schedule of work to be undertaken provided for the filling of 100,000 gaines, 200,000 fuse detonators, 200,000 T tubes, 200,000 primers and between 50 and 100 tons of cartridges weekly. In April, 1916, the filling of fuse No. 100 and assembling fuses or gaines were added. Output began during the first week in January, 1916. In a typical week (ending 18 May, 1917), the number of components filled was :—primers 140,000 ; detonators 170,791 ; gaines 37,185 ; fuses 42,210 ; T tubes 40,400 ; cartridges 53,300. The number of fuses and gaines assembled, tape-banded, and soldered amounted to 84,529. The total number of fuses filled during the war was 161,900 of No. 100 ; 269,700 of No. 102 ; 942,800 of No. 101 B, and 2,410,400 of No. 101 and 101 E types, making a total of 3,784,800. The total number of T tubes filled amounted to 5,141,000. The output of primers was 16,015,400 ; of cartridges 3,640,100 ; and of detonators 10,608,400.

The labour employed in the factory in March, 1917, consisted of 1,624 women and 194 men. In October, 1918, the total number was 1,096 and the percentage of women 85·8 per cent.

The capital expenditure to 31 March, 1918, amounted to £116,400.

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[1] C.R./Filling/23; C.R./Filling/68; HIST. REC./H/1340/1 ; HIST. REC./R/400/57; HIST. REC./R/1122.3/26, 63.

National Filling Factory No. 9, Banbury.[1]

The lyddite filling factory at Banbury took the place to some extent of the factory for amatol filling which had been projected near Watford, but which was abandoned owing to the unsuitability of the site.[2] After an examination of various localities in the south-west of England, a suitable site of 142 acres (afterwards increased) was found at Banbury, in December, 1915. The factory was designed by the managing director appointed by the Ministry, and the contract for building was let to a London firm.

Construction began on 28 January, 1916. The first plans provided for a capacity to fill 100 tons of lyddite into shell per week, but at the end of April, 1916, it was decided to extend the factory to include a second unit with a similar capacity to the first. The necessary plant was provided by transferring to this factory the lyddite plant ordered for Hayes, as the buildings for it in course of erection at Hayes were required for other purposes.

The first shell were filled on 25 April, 1916, and the total output to the time of the Armistice was 3,865,600 shells of various calibres. In September, 1917, a beginning was made in filling H.2 mines with ammonium perchlorate for the Admiralty and from then until 7 September, 1918, when this allocation ceased, 20,400 mines were filled. In February, 1918, the allocations for mine and lyddite shell filling were curtailed, and filling of 60-pr. and 6-in. shrapnel shell was begun. During the summer, the factory began charging, head filling and assembling chemical shells. The total output of the different natures of shell was as follows:—18-pdr. chemical 250,600; 6-pdr. C.P. 225,600; 60-pdr. H.E. 822,200; 60-pdr. shrapnel 608,600; 4·5 in. chemical 93,400; 6-in. gun shrapnel 67,000; 6-in. howitzer H.E. and chemical 1,449,900; 8-in. H.E. 16,200; 9·2-in. howitzer H.E. 332,100.

The number of workers employed at the factory in March, 1917, was 993 men and 548 women. In October, 1918, the women were 52·3 per cent. of the whole number (1,463). The capital expenditure to 31 March, 1918, amounted to £174,000.

National Filling Factory No. 12, Cardonald.[3]

Upon 9 September, 1915, it was arranged that Nobel's Explosives Company should undertake the erection and administration of a factory for filling minor components, a scheme which had been under discussion during the previous month.

A site was selected near Cardonald Station, on the Glasgow and Paisley Joint Railway, which was conveniently situated both for the supply of labour and the transport of materials. The building contract was placed with a Glasgow firm and a representative of the Office of

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[1] HIST. REC./H/1340/1; HIST. REC./R/1122.3/51; HIST. REC./R/400/57; HIST. REC./R/1122.3/26; C.R./Filling/62.

[2] *See* also Hayes (p. 166, below).

[3] HIST. REC./R/1122.3/42; HIST. REC./R/400/57; HIST. REC./R/1122.3/26; HIST. REC./H/1340/1; C.R./Filling/133.

Works was appointed to supervise and collaborate in the work. Construction began on 18 October, 1915, and in spite of some delay caused by snow storms, building was practically complete by the end of the year.

The factory was designed for a filling capacity of 200,000 detonators, 150,000 primers, and 100,000 T tubes per week. Output began on 24 January, 1916, and the number of components filled between that date and the signing of the Armistice was 38,418,600 detonators of various types; 24,603,700 primers and 10,074,300 T tubes.

In March, 1917, the number employed at the factory was 747, of whom 701 were women. In October, 1918, the total number was 475 and 89·2 per cent. were women.

The capital expenditure to 31 March, 1918, was £63,500.

National Filling Factory No. 6, Chilwell.[1]

When the question of the location of the various factories to be erected for filling heavy shell was under consideration, it was agreed that the neighbourhood of Nottingham would be a convenient locality for a central shell filling factory where the empty shell from the northern and midland manufacturing centres could be intercepted on their way to the coast for embarkation. In August, 1915, Viscount Chetwynd, a director of Messrs. Vickers, Ltd., was appointed managing director of a factory in this area, which was to be the main factory for filling shell of heavy calibre. He found a site at Chilwell, five miles south-west of Nottingham. The land, which consisted of 208 acres, was taken by agreement. Lord Chetwynd was entirely responsible for the lay-out and equipment of the factory, and for its construction, which was carried out by a London firm and began in the middle of September, 1915. The factory was divided into two parts, north and south, with a road running between them. On the north side were the ammonium nitrate mill, the T.N.T. mill, the amatol mixing house, the press houses, experimental buildings, changing rooms, canteens, offices, magazine reservoir, and other smaller buildings. To the south were the ammonium nitrate shed, T.N.T. store for the T.N.T. mill, the boiler and power station, the filled shell store, the empty shell store with the melt house adjoining it, railway sidings and other buildings and stores.

The lay-out provided for a capacity for making 1,000 tons of pressed and 500 tons of melt amatol per week, and filling this amount into shell of 60-pr. calibre and upwards. Some smaller shell were filled during the first few weeks of the factory's operations, when the supply of heavier natures was not equal to the filling capacity available. The Chilwell process had the following characteristics:—the ammonium nitrate and T.N.T. were ground separately to a high degree of fineness; they were then mixed for about ten minutes in a machine which did not grind them together, and the amatol thus made was taken immediately to the press houses and used so quickly that it was actually

[1] D.D.G.(C.)/C.M.G./336/14; D.D.G.(C.)C.M.G./336/6; C.R./Filling/299; HIST. REC./H/1340/1; HIST. REC./R/1122.3/26, 48; HIST. REC./R/400/57; D.D.G.(C.)C.M.G./336/31; C.R. 2594.

warm when pressed into the shell. This enabled advantage to be taken of the change in the state of the ammonium nitrate which occurred on cooling. In contrast with this, the method adopted at other National Filling Factories consisted in grinding together for about twenty-five minutes in a gunpowder mill with heavy iron rollers comparatively small charges of rather coarse ammonium nitrate and flaked or lumpy T.N.T. This effected an "incorporation."

The first trial shell were filled in January, 1916, regular output began in February, and the factory filled a large proportion of the heavier natures of H.E. shells for the 1916 summer campaign. Screw-stemming machines for filling cold amatol were introduced in the spring of 1917, and a good deal of experimental work in connection with the development of machinery was carried out at the factory. By the end of 1918, the factory had filled a total number of 19,342,700 shells, made up as follows: 60-pdr. H.E. 3,020,100; 4·5-in. H.E. 45,000; 6-in. gun H.E. 254,900; 6-in. howitzer H.E. 11,159,200; 8-in. H.E. 2,927,000; 9·2-in. gun H.E. 8,900; 9·2-in. howitzer H.E. 1,753,000; 12-in. howitzer H.E. 162,500; 15-in. H.E. 12,100.

On 1 July, 1918, a serious explosion took place in the amatol mixing house where amatol was prepared for filling by pressing. So far as it was possible to ascertain definitely the cause of the accident, the Home Office Committee of Enquiry considered that it was probably due to the presence of a piece of machinery in one of the mixers. The number of workers killed was 134; a few were seriously injured, and a large number slightly injured. The mixing-house and its extension, and the T.N.T. mill, were completely destroyed; and the power-house buildings were severely damaged. Work was, however, resumed in the melt section on the following day, and immediate steps were taken for the reconstruction of the factory, which only ceased work upon the signing of the Armistice. Under the new lay-out, the mixing-house was to be divided into four, to reduce the possibility of damage, and the buildings were constructed of steel, for the sake of speed.

In March, 1917, the number of workers employed was 7,452, of whom 5,722 were men. The large proportion of men compared with that in many of the filling factories was due to the heavy natures of the shells filled. A certain amount of difficulty was experienced, especially in the early stages of the factory's existence, in obtaining labour of the right type.

The capital expenditure to 31 March, 1918, was £2,712,100, and a sum of £250,000 was sanctioned for reconstruction after the explosion.

National Filling Factory No. 10 *or* 21, *Coventry.*[1]

In the summer of 1915, the Ministry suggested that Messrs. White and Poppé, who owned large engineering works at Coventry, and were acting as sub-contractors to one of the great armament firms, should undertake the erection and control of a factory for filling graze fuses (No. 100). A site of some 109 acres belonging to the firm and adjacent to their own factory, was acquired by agreement, and by 23 July,

[1] HIST. REC./R/1122.3/26, 66; 400/57. HIST. REC./H/1320/1.

1915, the preliminary plans for a factory, with a capacity for filling 150,000 fuses, 150,000 gaines, and 300,000 detonators weekly, were ready. The building contract was placed with a local firm, but owing to difficulties with regard to the railway sidings, construction only began on 12 September, 1915, and it was not until some time later that the scheme for the railway sidings was finally settled. In addition to this cause of delay in the completion of the factory, great difficulty was experienced by the contractor in obtaining building labour. Towards the end of 1915, too, a hurricane occurred which did considerable damage to the work already done, so that it was not until March, 1916, that building was sufficiently advanced to admit of beginning output. In February, 1916, financial sanction was given for the extension of the factory to include a unit for filling time fuses, No. 80, and building began in March.

The agency agreement with Messrs. White and Poppé was based on the payment of a definite sum for each component filled, with a minimum annual sum to cover agents' fees on each unit of the factory.

By the end of September, 1916, the factory had reached a weekly output of 150,000 No. 100 fuses, 150,000 gaines, 300,000 detonators for fuse No. 100, and the same number for gaines, while in addition a certain number of T tubes was being filled. The total number of fuses filled during the war was as follows :—No. 80/44, 50,300 ; No. 80, 2,029,900 ; No. 100, 2,695,800 ; No. 106, 7,285,600 ; No. 103, 2,004,000 ; Nos. 101 and 101 E, 7,355,000 ; No. 131, 10,100 ; No. 12, 14,200 ; making a total of nearly 21½ million.

During the autumn and winter of 1916-17, numerous prematures were reported from France, a large proportion being fused with fuses filled at this factory. Similarly, prematures at gun-proof occurred with numerous fuses and gaines which had been filled at Coventry. On examination it was found that there were many cases of careless assembling, *e.g.*, detonators were found upside down. The issue of fuses and gaines filled at Coventry was stopped, and on 30 December, 1916, the use of ammunition containing fuses filled at this factory was prohibited. Further examination served to point to the fact that the 1·78-grain detonators, which were being supplied to the factory, were unduly sensitive and were to some extent the causes of the prematures. The issue of the detonators was stopped pending special tests, and the contract for them was cancelled. The factory was entirely re-organised, and on 7 February, 1917, instructions were given for all fuses and gaines filled there, prior to the reorganisation, to be emptied and re-filled. The number of the factory was then altered to F. 21, as ammunition marked F. 10 was not unnaturally regarded with suspicion by the men in the field.

In September, 1917, the supplies of filled No. 80 fuses in stock, and the capacity available for filling, rendered the continuance of the Coventry factory on this work unnecessary, and the 80 fuse-filling section was, therefore, handed over to the Controller of Aeronautical Supplies. A year later it was found that increased filling capacity for this fuse was again required, and as the factory was no longer needed for aeroplane work, it reverted to its original use.

In March, 1917, the labour employed consisted of 3,357 women and 507 men. In October, 1918, women were 90·3 per cent. of the whole number (2,780). Temporary hostels were erected for the women workers.

The capital expenditure to 31 March, 1918, was £813,400.

National Filling Factory No. 22, Gainsborough.[1]

In September, 1917, negotiations were opened between the Admiralty and the Ministry with a view to the erection and control by the Ministry of a factory for filling sinkers with T.N.T. A site of 143 acres was chosen at Gainsborough, the preliminary plans were settled by 21 November, and the Office of Works began construction three days later. The control of the factory was in the hands of a managing director appointed by the Ministry, as direct control was considered desirable in view of the secret nature of the work.

The first sinker was filled on 14 February, 1918, and four were sent to Portsmouth on 18 February. Owing to the shortage of empties, regular output did not begin until 11 March, but from that time the supply improved, and on 25 June a maximum output of 70 sinkers in 24 hours was reached. The output was then reduced to 250 per week, and later to less than 200. From the end of September, however, until the Armistice, a weekly output of 200 was maintained. At the end of August the filling of H.2 mines with ammonium perchlorate was begun, and from 7 September until 11 November the output of these was 250 per week. In September, trench howitzer bombs were sent to the factory for storage and emptying.

The total number of sinkers filled was 5,522, representing 5,547,518 lbs. of T.N.T. The number of H.2 mines filled was 2,393, containing 383,860 lbs. of ammonium perchlorate.

At the end of October, 1918, the number employed in the factory was 322, of whom 53·4 per cent. were women. The total capital expenditure to 31 March, 1918, was £52,000.

National Filling Factory No. 4, Georgetown.[2]

In the summer of 1915 the Ministry decided to erect four national Q.F. ammunition filling and assembling factories, one of which should be in Scotland. A committee[3] was appointed by the Director of Munitions for Scotland, to act as the Board of Management of the factory. Its first meeting was held on 6 September, 1915.

The site chosen for the factory was an area of about 250 acres at Fulwood, Erskine, Renfrewshire, on the main Caledonian Railway line from Glasgow to Greenock, and on the Rivers Gryfe and Dargavel.

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[1] HIST. REC./R/1122.3/41 ; C.G.A.F. 349.

[2] HIST. REC./R/1122.3/35 ; 1122.3/26, 400/57 ; D.D.G.(C) C.M.G. 334.

[3] The members of the Committee were :—W. Melville, Esq., C.E., Chief Engineer Glasgow and South Western Railway Company, J. Dalrymple, Esq., C.A., General Manager Glasgow Corporation Tramways, J. Miller, Esq., F.R.I.B.A., and R. J. Smith, Esq., C.A.

The land, which had been formerly used for agricultural purposes, was almost level, and removed from dwelling-houses, while its surroundings allowed for expansion. The district was named by Mr. Lloyd George, at the request of the Board of Management, on the occasion of his visit on 24 December, 1915. Constructional work began on 25 September, 1915.

The capacity, as intended in October, 1915, was to provide for assembling Q.F. ammunition 18-pdr. to 4·5-in. up to 40,000 rounds per week, manufacturing 200,000 B.L. cartridges and filling shells up to 60-pdr. with block charges. Later, provision was made for filling 20,000 primers per week, and the assembling of fuses and gaines was also undertaken. In February, 1916, in order to increase the capacity for shell-filling by pressing cold 80/20 amatol, arrangements were made for the erection and control of an additional unit, adjacent to the existing one, capable of (*a*) storing, mixing and incorporating 300 tons of amatol 80/20 charges, and filling weekly, on double shift, 160,000 18-pdr., 50,000 4·5-in., 15,000 60-pdr. and 15,000 6-in.; and (*b*) melting and filling 150 tons of amatol 40/60 into shell of from 4·5-in. to 8-in. calibre, and on emergency 9·2-in. The construction of this second factory was begun early in March, 1916.

At the end of January, 1916, output began with the filling of 60-pdr. cordite cartridges, and in March the first shrapnel shell were filled (18-pdr. and 4·5-in.). Block filling began early in April. The total output of the factory from March, 1916, to the end of 1918 consisted of about 19,300,000 shells, 26,842,300 cartridges, 32,472,500 components, and 11,500 6-in. trench mortar bombs. The last named were filled from July to November, 1918, only. The shell filled included Russian and Roumanian, as well as star shell, the total output of the principal natures being as follows :—18-pdr. H.E., 7,986,600; 18-pdr. H.E. anti-aircraft, 4,900; 18-pdr. shrapnel, 5,093,000; 13-pdr. 9-cwt. H.E., 440,800; 3-in. 20-cwt. H.E., 114,800; 60-pdr. shrapnel, 654,300; 4·5-in. H.E., 2,898,400; 4·5-in. shrapnel, 6,400; 6-in. howitzer H.E., 2,040,400; 9·2-in. howitzer H.E., 7,700; 12-in. howitzer H.E., 45,900.

An important feature at Georgetown was the experimental work carried out in the factory. In July, 1916, experiments were made in a method of shell filling which obviated the necessity for the expensive machinery required for pressing, and at the same time was more economical than melt filling, which involved the use of at least 50 per cent. of T.N.T. By this method hot dry ammonium nitrate was mixed with molten T.N.T. in the proportion of 80/20 in a steam jacketed pan, and filled into shell by hand stemming and light malleting. Later a Hind and Lund machine was substituted for hand mixing, and the stemming was carried out by means of a light pile-driver instead of with a hand mallet. As a result of these experiments 80/20 hot mixed amatol was recommended by the Ordnance Committee in December, 1916, for general approval as a service filling. Experiments were also made in filling shell by machine, and in May, 1917, after various trials, a horizontal worm screw-filling machine was installed in the melt houses. Two others were added later, and the machine was officially

recognised as being the right type for filling by the "hot mixed" process. In 1917 also means were devised of sectioning filled shell which had been fired and recovered, in order to ascertain the effect upon the filling of the shock of discharge.

Labour was chiefly drawn from Glasgow and other neighbouring towns, but a considerable number of workers came from the Western Highlands and Islands, and also from Ireland. In March, 1917, the number employed was 12,837, consisting of 12,024 women and 813 men. In October, 1918, there were 11,344 employees, the percentage of women being 85·2. Between March, 1916, and November, 1918, five lives were lost through explosions and forty-one accidents occurred which caused serious personal injuries.

The estimated cost of construction in February, 1916, was £264,100. The actual expenditure to 31 March, 1918, owing to the extensions and developments required (including the construction and equipment of the amatol factory) was £1,368,400. The cost of working was increased by the exceptionally large area over which the factory buildings were dispersed.

National Filling Factory No. 5, Gloucester.[1]

The factory at Gloucester was one of the four Q.F. filling and assembling factories which the Ministry in the summer of 1915 decided to erect.

A Directing Board was formed[2] and began to consider plans in September. A site of 308 acres of agricultural land was selected at Quedgeley, about three miles south of Gloucester, on the west side of the Midland Railway main line, between Gloucester and Bristol. The erection of the factory began on 20 October, 1915.

The factory was originally planned to provide capacity for filling 40,000 rounds of 18-pdr. shell and 250 tons of B.L. cartridges per week, and for assembling fuses and filling these and other minor components. Production began on 13 March, 1916, and up to the time of the Armistice the total output consisted of 4,513,100 18-pdr. H.E., 5,768,900 18-pdr. shrapnel, and 384,300 4·5-in. shell filled and assembled, 17,600 60-pdr. shrapnel shell filled, 7,005,700 cartridges filled, 2,511,300 fuses assembled, 566,900 No. 106 fuses, 11,501,500 primers, 8,489,100 trotyl exploder bags and cartons filled, and 503,000 C.E. pellets compressed for fuse 106.

The women required for the work of the factory were drawn from Gloucester, Cheltenham, Stroud and neighbouring villages, and no difficulty was experienced in finding the numbers needed. The supply of male labour was a less easy matter, as the factory had to compete with several engineering works in Gloucester which were already engaged on Government work. Of the male workers employed the majority were either unfit or over age, for military service, or boys under 18. In March, 1917, the factory had on its books 720 male

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[1] HIST. REC./R/1122.3/43 ; 400/57 ; 1122.3/26.

[2] The members of the Board were : J. J. Macgregor, Esq., J. H. Beach, Esq., Harley K. Butt, Esq., and John Fielding, Esq.

employees and 5,644 women, making a total of 6,364. In October, 1918, 81·4 per cent. of the total number (6,227) were women. The first 70 women were trained for six weeks at Woolwich, the rest received their training in the factory.

The total capital expenditure to 31 March, 1918, was £410,400.

National Filling Factory No. 7, Hayes.[1]

Filling Factory No. 7 originated as one of the four factories for filling minor components situated in the London area.[2] Mr. A. C. Blyth, who at the request of the Ministry, had undertaken to look for possible sites in this area, found 200 acres of suitable land at Hayes, on the Great Western Railway from Paddington to Slough. Negotiations regarding the erection of the factory were opened on 9 September, 1915, and construction, which was placed in the hands of a London contractor, began on 18 September, 1915. Mr. Blyth, who was managing director on behalf of the Ministry at Southwark Filling Factory, received a similar appointment at Hayes, and continued to control the two factories until the Armistice.

The original designs provided for a filling capacity of 100,000 fuses, 300,000 fuse time rings, 200,000 primers, 300,000 T tubes, and 50,000 18-pdr. shell with block charges per week, as well as for filling cartridges as required and making detonators and primers. When, at the end of 1915, Southwark ceased to fill gaines, this work also was undertaken by Hayes.

In November, 1915, the managing director was instructed to arrange for the extension of the factory to include a shell-filling unit, which would supply a proportion of the capacity lost by the decision to abandon the plan of a shell filling factory at Watford.[3] This new unit was capable of manufacturing and filling into shell 200 tons of amatol per week and 100 tons of lyddite. It was laid out along the lines of the Filling Factory at Pembrey.

Production in the first factory began on 30 October, 1915, with the filling of 18-pdr. shell with block charges. In a typical week (ending 18 May, 1917), the output of filled shell and components from both units was as follows :—Shell, 31,293 ; cartridges, 89,170 ; friction tubes, 44,440 ; primers, 117,160 ; exploders, 272,000 ; detonators, 422,310 ; fuses, 177,098 ; gaines, 177,531 ; primer caps, 125,914. In addition 83,944 H.E. shell and 32,000 shrapnel were assembled ; 147,021 fuses, gaines and adapters were assembled, and 41,400 assembled fuses and gaines soldered. The total output of shell from both units up to the end of 1918 was as follows :—18-pdr. H.E., 4,977,100 ; 18-pdr. shrapnel, 1,828,200 ; 60-pdr. H.E., 86,600 ; 4·7-in. H.E., 23,300 ; 4·5-in. H.E., 4,855,400 ; 6-in. gun shrapnel, 37,800 ; 6-in. howitzer H.E., 572,400 ; 12-in. howitzer H.E., 200. The total numbers of fuses filled were 10,000

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[1] HIST. REC. /H/1340/1 ; HIST. REC./R/1122.3/16 ; HIST. REC./R/1122.3/26 ; HIST. REC./R/400/5 ; C.R./Filling/198 ; C.R./Filling/70 ; D.D.G.(C.)C.M.G.337/1 ; X235/167.

[2] *See* under Perivale (p. 173 below).

[3] *See* also under Banbury (p. 159 above).

of No. 80, 765,500 of No. 100, 5,582,800 of No. 106, 459,200 of No. 103, 1,598,500 of No. 102, and 8,315,200 of No. 101, making 16,731,200 of all types. The number of friction T tubes filled during the war was 3,864,000.

The labour employed in the factory in March, 1917, consisted of 8,780 women and 1,849 men, and in October, 1918, of 1,424 men and 8,375 women (83·3 per cent. of the whole).

The capital expenditure to 31 March, 1918, amounted to £899,000.

National Filling Factory No. 14, *Hereford.*[1]

On 20 March, 1916, the Minister sanctioned a proposal to erect a filling factory in the south-west of England, with a view to providing insurance against the loss of either Chilwell or Morecambe, the largest units for filling heavy shell. By the beginning of May of the same year, the necessity for an additional filling factory was enhanced by the increased demand for shell, and also by the fact that more picric acid was available for shell filling than there existed capacity to use it. A site of approximately 519 acres was found near Hereford by 6 June, 1916, and construction, which was undertaken on a lump sum contract to the lay-out made by the Office of Works, began on 12 July, 1916.

The control of the factory was in the hands of a managing director appointed by the Ministry.

The factory plans allowed for a filling capacity of 90,000 to 100,000 shells per week, which involved dealing with some 900 tons of explosive. Of this amount, 700 tons was to be amatol, and 200 tons picric acid. The picric section began output in November, 1916, and continued in operation until April, 1918. By that time, a marked improvement had taken place in the detonation of amatol-filled shell, and as the increasing stringency of imports made a reduction of the picric acid filling programme necessary, the section was closed down. It was re-opened in August, 1918, after the explosion at Chilwell, and continued in operation until the Armistice. The total output of filled shell from this section represented approximately 19,943,976 lbs. of picric acid.

The amatol section consisted of six units of 100 ton weekly capacity for pressed amatol 80/20 and one unit of the same capacity for hot mixed amatol. The total tonnage of explosive used in this section amounted to 5,850 tons of T.N.T. and 21,000 tons of ammonium nitrate. During the last month of the war, H.S. gas charging was undertaken and 7,200 shell were filled on behalf of the American forces.

The total output to the end of 1918 of the principal types of shell from both sections amounted to 1,000 18-pdr. chemical; 291,200 60-pdr. H.E.; 1,723,800 6-in. howitzer H.E. and chemical; 1,207,700 8-in. H.E.; 946,700 9·2-in. howitzer H.E., or a total of 4,170,400 shell.

In March, 1917, the total number of workers employed was 1,559, of whom 1,216 were women; in October, 1918, the total was 5,758,

[1] HIST. REC./R/1122.3/57; 1122.3/55; 1340/26, 31, 46; 400/57; 1122.3/26; D.D.G.(C) C.M.G./344.

and the women numbered 3,858 (66·8 per cent.). The supply of labour was a matter of considerable difficulty, partly owing to the situation of the factory in a district where the native sources were soon exhausted, and which had little or no attraction for imported workers. The heavy and monotonous nature of the work also had a deterrent effect on workers.

The capital expenditure to 31 March, 1918, was £1,281,300.

National Filling Factory No. 1, *Leeds.*[1]

The Filling Factory at Barnbow, near Leeds, was the first of the four Q.F. filling and assembling factories to be initiated by the Ministry during the summer of 1915. Its erection and control were in the hands of a Directing Board.[2]

The factory was laid out on a site of 296 acres, a mile to the west of Garforth Station, on the Leeds and Selby branch of the North Eastern Railway, and 5 miles due east of Leeds. Transport facilities were thus easily available, and it was not found necessary to find local housing accommodation for the workers. The erection of the factory began on 13 September, 1915.

According to the original plans the maximum weekly output was expected to be 200 tons of B.L. cartridges, 70,000 rounds of 4·5-in. Q.F. ammunition and 160,000 rounds of 18-pdr. H.E. shrapnel filled and assembled, and 80,000 primers filled and completed. Some experimental work was done in December, 1915, and early in January a continuous output began with the making up of 60-pdr. cordite cartridges. The first shell were filled in April, 1916, with 80/20 amatol block charges. Early in the year it was decided to incorporate with No. 1 Filling Factory the amatol factory which had been planned for erection at Otley. A new unit was therefore laid out, with a capacity for incorporating and stemming into shell 300 tons weekly of 80/20 amatol and 150 tons of 40/60 amatol melt. Construction began on 8 March, and the first shell were filled in the new unit on 18 April,1916. More than a year later, after the efficacy of the " hot mixed " method of filling had been proved, a fresh extension was built on to the melt house with the necessary equipment for this type of filling, and by August, 1918, the weekly output of filled shell from this unit had reached 50,000.

At the end of 1918 the total output of the factory since January, 1916, amounted to 9,062,800 18-pdr. H.E. ; 332,300 18-pdr. shrapnel ; 6,600 60-pdr. H.E. ; 184,400 60-pdr. shrapnel ; 13,308,600 4·5-in. H.E. ; 1,675,000 6-in. howitzer H.E., or a total of 24,569,700 shell. In addition 36,150,000 B.L. cartridges were filled and some millions of minor components.

In the spring of 1916, a box factory was established on the site, where gun ammunition boxes were both manufactured and repaired,

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[1] HIST. REC/R/1122.3/54 ; 11 ; 26 ; 7 ; X235/167 ; HIST. REC./R/400/57 ; D.D.G.(C) C.M.G./331/11 ; *Fourteenth Report of Standing Committee on Causes of Explosions.*

[2] The members of the Board were Joseph Watson, Esq., The Hon. Rupert Beckett, A. G. Lupton, Esq., Bernal Bagshaw, Esq., and T. L. Taylor, Esq.

after use, for further service. A useful piece of experimental work was carried out at the shell filling factory in the reclaiming of waste amatol. By means of a special apparatus for separating and remixing the ingredients, it was found possible to reclaim an average of 10 tons of T.N.T. and 40 tons of ammonium nitrate weekly. As a result of this success, similar plants were established in other factories.

The labour required for the factory was largely drawn from Leeds, but considerable numbers came from York, Wakefield, Harrogate and other towns, as well as from many of the villages within a radius of twenty miles. The Lancashire cotton mills also provided a certain number. In March, 1917, out of a total of 13,315 workers, 12,150 were women and 1,165 men ; while in October, 1918, the total number was 8,234, and the percentage of women 86·6.

The factory was unfortunate in experiencing a serious explosion in December, 1916, when a 4·5-in. shell burst, when being fired by machine, and set off others near it. Thirty-five women lost their lives, and many were injured. Two other explosions of a less serious nature occurred, in which five lives were lost.

The capital expenditure of the factory to 31 March, 1918, amounted to £813,200. The cost of building and equipping the box factory was an additional £260.

National Filling Factory, No. 2, Liverpool.[1]

The idea of erecting a filling factory at Liverpool originated at the time of Mr. Lloyd George's visit to the city in June, 1915. Railway and shipping facilities, proximity to industrial centres manufacturing empty shells and the fact that large quantities of unfinished 18-pdr. ammunition were being received at the port from America, all conduced to make the locality a suitable one for a filling factory.

The erection and control of the factory were put into the hands of a Directing Board nominated by the Liverpool Munitions of War Committee.[2] The Board held its first meeting on 4 October, 1915, but work on the plans and other preliminary arrangements were begun in July. The site finally selected for the factory, after considerable discussion, consisted mainly of Bland Park Farm, in the parish of Sefton, close to Aintree Station, about 175 acres in extent, but with room for expansion. The ground was level, and situated close to the Lancashire and Yorkshire Railway marshalling sidings, and also to the terminus of the Liverpool Corporation Tramway. Construction began on 18 October, 1915.

According to the original plans the capacity of the factory was to provide for completing 7,000 incomplete rounds of Q.F. ammunition, and cutting and making up 33 tons of cordite into B.L. charges per

[1] HIST. REC./H/1122.3/1, R/1122.3/50, 58, 26 ; HIST. REC./R/400/57 ; X235/167 ; D.D.G.(C) C.M.G./332.

[2] The members of the Board were Sir Benjamin Sands Johnson, Director of Johnson Bros. (Dyers) Ltd., Mr. Henry Bell Wortley, Ship Owner, of Alfred Holt and Company, Mr. Max. Muspratt, Chairman of the United Alkali Company, Ltd., and Hon. Sec. Mr. E. Cranstoun Given of Fortescue, Flannery and Given, Naval Consulting Engineers.

day, and filling 100,000 primers weekly. Work began at the end of January, 1916, when the first 8-in. howitzer cartridges were made up. In February, 1916, it was decided to extend the factory to include an amatol unit capable of mixing and stemming into shell 250 tons of amatol per week. The construction of this unit began on 10 March, and in July, 1916, it came into operation. In August, 1917, the Ministry established an experimental section at the amatol factory for improving the method of shell filling and useful work was done in the direction of machine filling both of shell and exploder bags. The total amount of finished ammunition was 5,426,000 18-pdr. H.E.; 6,875,700 18-pdr. shrapnel; 39,000 18-pdr. incendiary; 386,000 60-pdr. H.E.; 26,200 60-pdr. shrapnel, 95,700 4·5-in. H.E.; 25,600 4·5-in. shrapnel; 125,600 5-in. H.E.; 4,214,900 6-in. howitzer H.E.; 125,400 8-in. H.E., or a total number of 17,340,100 shells of various natures, while 24,000 tons of amatol and 1,000 tons of smoke mixture were made, 180,000,000 exploder bags, 2,500,000 exploder containers and 2,000,000 smoke bags were filled. In addition to these, 16,588,200 cartridges, 3,364,800 fuses and gaines were assembled, 291,900 No. 106 fuses, and 9,594,700 primers were filled.

The labour employed in the factory came from Liverpool, Wallasey, Ormskirk, and other places on the Lancashire and Yorkshire Electric Railway. In March, 1917, out of a total of 10,837 workers, 10,340 were women and 497 men. On 23 July, 1918, three lives were lost owing to the explosion of a 6-in. shell. In August, 1918, there were 8,599 employees, of whom 87·1 per cent. were women.

The total expenditure on the Q.F. and amatol factories to 31 March, 1918, was £725,400.

National Fuse Filling Factory, Luton.[1]

In the middle of 1916, Messrs. George Kent, Ltd., of Luton, undertook to erect and manage a factory for filling the No. 80 fuse. The site selected was at Chaul End, near Luton, where the firm had already erected a factory for fuse manufacture, and where additional land was available for the national factory.

By an agreement signed on 10 January, 1917, Messrs. Kent undertook to erect and equip, at government expense, buildings for filling fuses and for soldering and testing metal covers. To cover the cost of the fuse filling buildings, not more than £37,400 was to be paid to the firm, and in addition 2½ per cent. of the expenditure on the fees of architects, superintending engineers, etc. A further sum, which ultimately amounted to about £2,000, was to be allowed in respect of buildings and plant for soldering covers. The buildings and plant were to be the property of the Minister of Munitions, but the firm had an option to purchase them after the war.[2] The Ministry

[1] D.D.G.(C)/C.M.4/1547,Sec./Gen./1047.

[2] If the option were not exercised, the Ministry had the right to remove the buildings and plant, but should they not do so within a period of six months, the buildings and equipment would become the property of the firm. After the Armistice, the firm did not exercise their option to purchase, and the Ministry, not wishing to remove the buildings, purchased the site.

were to be responsible for expenditure on upkeep and repair and were to bear all costs of production, including wages, such costs to be ascertained quarterly. They were also to supply empty fuses and certain other materials. Delivery of filled fuses was to begin by 21 February, 1917, and to rise as quickly as possible to 50,000 per week. The agreement provided for a management fee, to be based on production costs, increasing as the cost decreased, but in no case exceeding $1\frac{1}{4}$d. for each fuse which passed inspection. Subsequently, however, the firm decided not to accept any management fee.

It was intended that the buildings should be completed and equipped by the end of January, 1917, but the time limit was considerably exceeded, largely owing to lack of building labour, and constructional work was not completed until the summer. In order to reduce expenditure, the original scheme of construction was modified, and the re-arrangement involved a reduction of filling capacity from 50,000 to 40,000 fuses a week. On 1 March, 1918, an explosion occurred, as a result of which portions of the factory had to be rebuilt and certain structural additions and alterations made to meet Home Office requirements, the estimated cost being £1,800. Extensions were undertaken from time to time, the most considerable being the erection of a magazine and mixing room, for which an expenditure of £2,420 was sanctioned in July, 1918.

In addition to filling No. 80 fuses, the factory undertook in October, 1917, to convert the No. 180 fuse to No. 80, working up to an output of 20,000 a week as soon as possible.

The employees numbered about 600, of whom over 90 per cent. were women.

National Filling Factory, No. 13, Morecambe.[1]

Negotiations with Messrs. Vickers regarding the erection and administration of a filling factory began in August, 1915. A site was found at White Lund, halfway between Lancaster and Morecambe, and thus conveniently placed for receiving empty shell from the projectile factory at Lancaster and other centres on the north-west coast, and for dealing with the heavy shell imported on the Mersey. Some 250 acres of land formerly used for grazing purposes were taken over under the Defence of the Realm Act. The building contract was placed by Messrs. Vickers with a Glasgow firm, on the basis of a percentage on prime cost, and construction began on 23 November, 1915. The agency agreement with Messrs. Vickers provided for the payment to the firm of a percentage on the net cost of building and equipment, and of a lump annual sum for the administration of the factory. Very considerable delays experienced in construction and starting up were attributed by the firm to the general uncertainty as to lay-out, since it was not until January, 1916, that the final decision as to the method of filling was given. Output began, ultimately, in July, 1916.

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[1] HIST. REC./R/1122.3/38; 1122.3/19; 400/57; 1122.3/26; HIST. REC./H/1340/1; D.D.G.(C)/C.M.G./343/1; D.D.G.(C)/C.M.G./343/2; C.R./Filling/321.

The buildings, of which by far the larger proportions were of wood roofed with felt, consisted of six danger units, 16 bonded stores (the property of the Army Ordnance Department), a paint shop, an empty shell store, stores and magazines, general offices and canteen, power station and workshop. This lay-out gave capacity for filling 500 tons pressed or 200 tons melted amatol weekly into shells of 60-pdr. to 12-in. calibre. The total number of shells filled up to October, 1917, was 2,893,100, made up as follows :—60-pdr. H.E. 117,900 · 6-in. howitzer H.E., 2,195,000 ; 8-in. H.E., 308,700 ; 9·2-in. howitzer H.E., 261,800 ; 12-in. howitzer H.E., 9,700. On 1 October, a disastrous fire broke out at about 10.30 p.m., on the upper floor of one of the melt plants. Fortunately, the workers had not returned from supper, so that the number of casualties—10 were killed and a few seriously injured—was small compared with the material destruction caused. Numerous explosions occurred, the last of which took place about 4 a.m., on 3 October, 1917, and by 8 a.m. on the following day the factory was almost entirely destroyed. By that time practically nothing was left except the filled shell stores, which the efforts of the fire brigades had been concentrated on saving, the paint shed, the explosives magazines and part of the power house. The cause of the original fire was not discovered. Just before the close of hostilities, the factory site was utilized for chemical filling and assembling, on account of its isolation and extent.

Labour was difficult to obtain in competition with local munition works, particularly on account of T.N.T. poisoning and low rates of pay compared with those for other work. A premium bonus system was introduced to overcome this last difficulty. In March, 1917, 1,225 men and 2,248 women were employed, and in September, there were 4,621 employees, of whom 2,957 (64·4 per cent.) were women. House-room was found for the workers under the arrangements made by Messrs. Vickers for housing their operatives at the Lancaster Projectile Factory.

The capital expenditure to 31 March, 1918, was £199,900.

National Filling Factory, No. 18, *Pembrey.*[1]

In May, 1915, a contract was made by the War Office with Nobel's Explosives Company for the construction at Pembrey, of a factory for the production of T.N.T. Under this contract, Nobel's were to provide a sufficient and suitable site for the erection of loading plant adjoining the T.N.T. plant. This loading factory was to be erected and equipped by the Explosives Loading Company, for filling shells, mines and torpedoes under contract. In consequence of the decision to take over the explosives factory at Pembrey,[2] the loading factory was also nationalised as from 1 January, 1917, and the Explosives Loading Company became the agents of the Ministry of Munitions for its administration. The site was held under lease from free-holders at an annual rental.

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[1] Hist. Rec./R/1122.3/49 ; 1124/6 ; 1122.7/12 ; 1122.3/26 ; 400/57.

[2] *See* above, p. 69.

The amount of H.E. which the factory was required to fill into shell was originally 100 tons per week, but this was later increased, and before the factory ceased this type of work the consumption of H.E. exceeded 200 tons weekly. The explosive at first allocated to the factory was purified T.N.T., but owing to the increasing need for economy in this material, amatol 40/60 was substituted for it.

Filling began on 2 July, 1915, and between that date and May, 1917, 1,143,000 shell sizes 8-in., 6-in. and 4·5-in. were filled. In May, 1917, the factory discontinued filling, and undertook the breaking down of defective ammunition and the recovery of components. Two amatol recovery units, each with a capacity for dealing with 50 tons weekly were installed, and from May, 1917, to December, 1918, 1,664,000 complete rounds of 18-pdr. and 13-pdr. H.E. were broken down, besides H.E. shell from 15-in. calibre downwards, shrapnel shell and aerial bombs and other forms of defective ammunition. In addition, 3,000,000 fuses, separated from their gaines, were dis-assembled.

The labour for the factory was at first supplied locally, but as the requirements increased workers were recruited from greater distances. The provision of special trains to and from Swansea and Carmarthen obviated the necessity for finding housing accommodation in the locality. In March, 1917, the numbers employed in the factory were 480 men and 570 women, making a total of 1,050. In October, 1918, there were 1,441 employees, 70·5 per cent. being women.

The capital expenditure on the factory to 31 March, 1918, amounted to £102,300.

National Filling Factory, No. 3, Perivale.[1]

Perivale was the first of the National Filling Factories for minor components projected in the London area, during the summer of 1915, with a view to filling empty components arriving from overseas. Its erection was arranged for by the Metropolitan Munitions Committee, at the Ministry's request, early in August, 1915, the site being inspected on 17 August. The site chosen was one of 120 acres at Park Royal in the Urban District of Acton. Construction began on 26 August, 1915. The administration of the factory was in the hands of a sub-committee[2] of the Metropolitan Munitions Committee until 30 June, 1916; from that date the operative side was directly controlled by the Ministry, but the Metropolitan Munitions Committee continued to be responsible for construction and equipment.

The factory was designed for a filling capacity of 200,000 fuses, 200,000 gaines, and 400,000 detonators per week. Later, friction "T" tubes and primers were included among the components filled. Output began on 1 December, 1915. By the middle of 1917, the number of components filled weekly had reached 1,800,000, in addition to

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[1] HIST. REC./R/1122.3/37; HIST. REC./H/1121.27/1; 1340/1; HIST. REC./R/400/57; 1122.3/26; D.D.G.(C)/C.M.G./333/1; HIST. REC./R/1320/10.

[2] The Sub-committee included Mr. F. Bailey, Mr. T. H. Restler, Mr. B. Hall Blythe, and a representative of the Ministry, Capt. C. L. Conacher, later, Mr. A. Ross.

which 120,000 fuses and gaines were being soldered into cylinders per week, for despatch overseas. The total output of filled fuses during the war was 28,078,900, made up as follows:—No. 100, 3,001,200; No. 106, 5,360,500; No. 103, 2,553,600; No. 102, 1,063,200; No. 101, 16,100,400. The total number of "T" tubes filled was 5,541,500.

In August, 1917, the Ministry established an experimental unit at the factory for the production of components under ideal conditions, with a view to improving the general standard of production. Elaborate tests were carried out and the information gained was communicated to all factories engaged on similar work. In the first quarter of 1918, the unit filled 5,300 fuses of No. 101 type, and during the second half of the year, 3,000 of No. 106 were filled.

Considerable difficulty was at first experienced in obtaining a sufficient supply of labour, and it was found necessary to send out women, who had been trained in the factory, to various towns to hold meetings and recruit workers. In March, 1917, the total number employed was 5,241, of whom 4,845 were women. In October, 1918, the total number was 2,198, and the number of women 1,956 (88·9 per cent.).

The capital expenditure to 31 March, 1918, was £519,600, exclusive of £3,200 for the Standard Production Unit.

National Filling Factory, No. 8, Southwark.[1]

The component filling factory at Southwark was established as an emergency factory in the late summer of 1915. An offer was made by a firm in Southwark to place the two upper storeys of a large warehouse in Sumner Street, at the disposal of the Ministry, but as a considerable number of workpeople were employed on the lower floors the use of the upper floors for handling explosives was regarded as too dangerous. A vacant site, however, of some 60,000 square yards was found adjacent to this building, and was considered suitable for filling the small components which were then urgently required. The land was unoccupied and its title in dispute. Possession was taken on 27 August, 1915, and construction began on 1 September under the personal supervision of Mr. A. C. Blyth, who controlled both this factory and the Hayes National Filling Factory on behalf of the Ministry. Some buildings were already standing when the property was taken, and the whole factory was in working order in from fifteen to twenty days. In ten days from the date when building began the filling of gaines started, in order to meet the serious deficiency in the supply of these components. Regular output started on 1 October. In December, 1915, gaine filling with tetryl ceased in view of its danger and the congested nature of the district. The factory was intended to deal with all classes of components in emergency, and was laid out for assembling 5,000 No. 100 fuses weekly as well as detonators, primers, etc. The amount of explosive which it was necessary to keep in store for these components at any one time was so small that it could not be regarded as dangerous to the population of the district. The factory's total output of filled fuses was 8,856,800, made up of 2,035,900

[1] Hist. Rec./H/1340/1; Hist. Rec./R/400/57; 1122.3/26; C.R./Filling/43, 74.

of No. 100 ; 1,201,200 of No. 103 ; 681,000 of No. 102 ; and 4,938,700 of No. 101. In the spring of 1918, all filling operations ceased in this factory, and in April, 1918, it was transferred to the Anti-Gas Authorities as an inspection depôt for protective clothing. Later still it was used for storing the Ministry archives.

In March, 1917, the employees numbered 912, of whom 801 were women. The numbers gradually decreased, and in February, 1918 they were 381, with 335 women (87·7 per cent.).

The capital expenditure to 31 March, 1918, was £41,100.

III. Individual Trench Warfare Filling Factories.[1]

Trench Warfare Filling Factory, Denaby.

A factory for filling 3-in. Stokes bombs was built on a seven-acre site adjacent to the ammonal factory of the British Westfalite Company at Denaby, near Rotherham, co. Yorks. The land was leasehold of the company, and the buildings were erected at Government cost to plans agreed between the company and the Department, the actual orders being placed by the company's representative. Constructional work began about the middle of August, 1915, and the original buildings, except certain storage sheds and a changing room, were completed by mid-February, 1916. Additional land was taken up in the following March to meet the extended Stokes bomb programme, and the new buildings, consisting of ten filling sheds, were completed by the following July.

The method of administration was under discussion between the Department and the company between August and December, 1915. The contract price asked per box of three bombs was at first 3s. 6d., afterwards 1s. 9d. From 1 January, 1916, the factory was nationalised under an agency agreement, the company accepting £250 to cover all supervisory duties up to that date. Under the final agreement, which was dated 24 May, 1916, and was retrospective, the company undertook to fill 3-in. Stokes bombs at a fixed yearly fee and a bonus of £1 per thousand bombs satisfactorily filled. The Minister defrayed the cost of production including labour, light, heat, transport and material except the explosive, which was charged to the agents at a fixed rate. The buildings and equipment were to be the property of the State until twelve months after the termination of the war or the determination of the contract, which ever should be the later. The agreement was thus very similar to that for agency shell-filling factories ; but an important variation was introduced at the instance of the company, whereby the Minister indemnified them, not only against loss by fire or under the Employers' Liability and Workmen's Compensation Acts, but also against loss of profit and damage at their adjacent explosive factory arising out of any accident at the national factory. The labour was controlled by the agents, but the Minister had power to dismiss workers or vary the rate of wages, and a technical representative of the department was resident at the factory.

[1] For the authorities on which these accounts are based, *see* HIST. REC./H/1600/9.

The factory was laid out to fill 75,000 3-in. Stokes bombs weekly, serving as a centre for the empty bombs made in the northern counties. In January, 1917, a clearing-house for these bombs was established at Rotherham to prevent congestion at the factory, where they were loaded and packed into boxes with their components ready for direct issue overseas. Filling began in small quantities on 11 December, 1915, on a large scale 29 January, 1916. In June, 1916, work was stopped temporarily on account of congestion due to lack of delivery instructions. In the following August it was decreased by half, special arrangements in reducing hours of work being made to enable the maximum output to be re-established. This was done in the following August, and in the spring of 1917 a weekly output of 90,000 was reached without introducing night-shifts. At this time this factory was the sole source of supply for bombs of this nature. In April, 1917, work was entirely suspended for a few days during a change-over in the design of bomb. It was subsequently partly occupied in disassembling obsolete 3·7-in. trench mortar bombs. Filling of 3-in. Stokes bombs was gradually resumed in June, 1917, and output rose to 110,000 weekly by the end of August. Arrangements were then made to increase the capacity still further in order to fill bombs for the Allies. This was done without incurring additional capital expenditure, and the factory continued loading 3-in. Stokes bombs until the termination of hostilities.

Several improvements in methods of filling originated in this factory. Early in 1916 a new steel drift was introduced, and in January, 1917, a novel pattern of filling bench was installed which reduced the loose ammonal to a minimum. The filling was done entirely by hand. The weekly average of workers employed during 1916 was 359, during 1917, 405. By far the greater number were women, and in May, 1917, the transport arrangements were reorganised to enable 27 men to be replaced by women.

Denaby was regarded as a peculiarly successful factory, both in economy and efficiency. The capital expenditure was estimated in February, 1916, at £6,000; in December, 1917, at £13,066. The actual expenditure down to 31 March, 1918, was £14,710.

Trench Warfare Filling Factory, Erith.

The Erith factory for filling 2-in. trench mortar bombs was built on grazing land adjacent to the Thames Ammunition Works on the Crayford Marshes. It covered an area of 14 acres and was two miles from Slades Green Station, from which a siding was laid. The buildings were partly adapted from packing sheds and magazines belonging to the Thames Ammunition Works, partly erected at state cost. The filling station proper was on leasehold land of that company; the receiving and distributing sheds were on the adjacent leasehold of an interned Austrian, which was taken under the Defence of the Realm Act. Instructions were given to the Thames Ammunition Company for the erection of the factory on 21 August, 1915, and the filling sheds were completed by the end of the following January. There were eighteen sheds in all.

An agreement with the Thames Ammunition Works for operating the factory was under discussion between August, 1915, and the following January. The alternatives proposed were :—(1) The Minister to rent the site and bear the cost of construction, the contractor filling the bombs at a flat rate and paying a nominal rent for the buildings ; or (2) the firm to fill on a cost plus percentage basis ; or (3) (suggested in December, 1915) an agency agreement similar to the Denaby agreement and to cover filling operations only, the receiving and distributing station to be directly controlled by the Department. From 27 January, 1916, the factory was taken over under the Defence of the Realm Act, owing to the failure to come to reasonable terms with the contractor and the receipt of adverse reports on the general conditions, particularly as regarded danger regulations and female labour.

Throughout the war the factory was engaged in filling ammunition for the standard medium mortar. Work on 2-in. bombs began in the week ending 2 October, 1915. In the following January the factory undertook the entire filling programme for this nature. It was originally laid out for 20,000 bombs weekly and was extended to deal with 25,000 in April, 1917, when output had already exceeded 20,000 owing to the high efficiency attained. In May, 1917, the lay-out was reorganised for filling 6-in. trench mortar bombs instead of 2-in., the filling of which was entirely transferred to Watford No. 1 in the September following. Gravity conveyors were installed for handling the heavier 6-in. bombs. Filling of this nature began at the end of May, 1917, and continued until the termination of hostilities. The total output of 2-in. bombs was 1,142,806, and of 6-in. bombs 1,063,193. It was decided in June, 1917, that no further extensions would be practicable in view of the difficulty in obtaining labour.

The district was sparsely inhabited and labour only available from a distance and in competition with many other munitions works. Workers were brought by motor transport and later by rail when the siding was completed. Canteens provided breakfast, dinner and tea. The average weekly number of employees in 1916 was 350 ; in 1917, 400. Five-sixths were women, the remaining sixth, men. A flat time-rate was paid with a bonus on the quantity filled. The high piece-rates at Woolwich drew away considerable numbers, so that the whole *personnel* of the factory was changed about once in every three months.

The capital expenditure was estimated at £24,000 in February, 1916, at £35,042 in December, 1917. The actual expenditure down to 31 March, 1918, was £42,041.

Trench Warfare Filling Factory, Fulham.

In August, 1915, W. E. Blake, building contractor, agreed to erect a factory for grenade filling. He formed a special company, the W. E. Blake Explosives Loading Company, for the purpose, and built the factory on three acres of waste ground at Stevenage Road, Fulham, on the south bank of the Thames, obtaining a lease of the site from the Ecclesiastical Commissioners. It was adjacent to Mr. Blake's grenade factory and lay in the midst of a very crowded district. The magazines were established at a distance on disused playing fields at Worm Holt

Farm, Shepherd's Bush. Transport was organised by barge to Deptford and thence by rail to Newhaven.

The factory was originally built for loading 80,000 Ball grenades weekly, and the filling of Ball, Mills, and other types of grenades was carried on under contract until January, 1916. A scheme for converting the factory to a station for filling 3-in. Stokes ammunition was initiated in October, 1915, and experimental work on these bombs began on 21 October. In the following December negotiations with the contractor for continuing bomb-filling under an agency agreement fell through. Shortly afterwards adverse reports were received as to safety conditions and accommodation for workers. In view of these facts and the failure to come to reasonable terms the factory was nationalised under the Defence of the Realm Act as from 11 February, 1916. By that date grenade-filling had been transferred elsewhere. During February and March the factory was reconstructed and reorganised, and was the first to load 100,000 3-in. Stokes bombs in a single week. In June, 1916, this work was reduced to 50,000 weekly owing to the accumulation of filled bombs. In the September following it was again decreased to 23,000 weekly, and from January, 1917, the loading of these bombs was gradually transferred to Denaby.

The factory began pyrotechnic work in June, 1916, with the filling of flares. By the following January a record standard of efficiency had been reached, and the first 1,110,000 were completed by 24 February, 1917, when work began on another million. These were finished by the end of March. Plant for filling and assembling Véry signal cartridges was installed in April, 1917; output began within three weeks, and by mid-June experiments had led to the improvement of manufacturing methods with a corresponding increase in production.

Grenade filling began again in November, 1916, and eventually became the leading work of the factory. Pneumatic apparatus was invented for filling Mills grenades and the plant was installed in December, 1916, reducing the labour employed on this work by 90 per cent. and the cost by £2 per 1,000. This machine enabled a single girl worker to obtain a record of 6,000 grenades filled in a nine-hour day. Grenade-filling continued until the Armistice, six different kinds being handled while the factory was under national control.

Miscellaneous work upon minor components began with the filling of Stokes propellant rings in August, 1916, and the assembling of Midgeley fuses for aerial bombs in November, 1916. The factory also undertook a considerable amount of experiment, such as the filling of bombs and grenades with amatol to test its suitability in these stores and the adaptation of the 3-in. Stokes bomb for incendiary purposes. The introduction of economical methods at Fulham enabled contract prices to be reduced. Thus, a comparison of costs in the manufacture of cordite rings enabled flat rates to be established with a saving of £2 10s. per 1,000. The miscellaneous character of the work is illustrated by a week's output in September, 1918, which included three types of grenade, five of pyrotechnics, experimental bomb-filling, the manufacture of cordite rings, quick-match and ignition papers and the breaking down of charges.

The local labour supply was ample and day shifts only were worked. The proportion of women to men was 15 to one. A flat rate was always paid. The average number employed weekly in 1916 was 485, in 1917 462, and in 1918 it was still below 500. A canteen was opened under arrangement with the Central Control Board in May, 1916.

The estimated capital expenditure in December, 1917, was £16,860. The actual expenditure down to 31 March, 1918, was £19,684, being limited to the lowest amount possible in view of the temporary character of the factory.

Trench Warfare Filling Factory, Watford No. 1.

This factory was built on 20 acres of agricultural land at Balmoral Road, about two miles from Watford Junction. It was adjacent to the national factory for the manufacture of ammonal, erected at Watford by the Explosives Supply Department. It occupied part of the site taken over under the Defence of the Realm Act for that factory. The project for the filling factory dated from 3 September, 1915. The lay-out was partly based on the Woolwich and Erith bomb-filling shops; the building were necessarily scattered, owing to the existence of a "pot-hole" in the middle of the site. General authority for the expenditure was obtained by the Trench Warfare Department about 4 October, 1915. The original buildings, consisting of about 19 sheds, were completed by the second week in February, 1916. From the first the factory was directly controlled by the department, and was managed by a superintendent, a volunteer, who afterwards took responsibility also for Watford Factory No. 2.

The factory was intended to load 2-in. trench howitzer bombs with ammonal from the neighbouring explosives factory, and to pack the filled bombs with their components for issue overseas. Work began on 16 October, 1915, with the filling of 3-in. Stokes bombs, which was undertaken temporarily, and ceased on 8 January, 1916. The maximum output of 2-in. bombs obtained was 20,000 weekly. The filling of this nature began on 20 December, 1915, and continued until the second week in January, 1917. It was then suspended for seven months, during which 2-in. bombs were filled at Erith only. It recommenced on 7 July, 1917, and from the end of the following September all 2-in. ammunition was filled here until the change over to 6-in. bombs took place at the end of the year. The examination and assembling of fuses began in the second week of March, 1916, and new assembling rooms were completed for this purpose early in May. From April, 1916, till the following August the filling of first deliveries of 9·45-in. bombs was undertaken, pending the construction of Watford No. 2 Factory. Work on assembling chemical, incendiary, and smoke bombs began with experimental lots of 4-in. Stokes bombs in the second week of May, 1916, and reached a commercial scale at the end of July. In July, 1916, special sheds, partitioned by hempen rope mantlets, were erected for the particularly dangerous operations of filling ophorite gaines for chemical bombs, and filling 2-in. bombs with thermit. Additions were made to these sheds during the first six months of 1917, when the greater part of the capacity of

the factory was concentrated upon these operations. Some work was also done in filling the exploders of 6-in. artillery shells filled with chemicals. In January, 1917, the factory began assembling components for the 9·45-in. ammunition, and in the following April it undertook the entire assembling of components for 3-in. Stokes bombs made in the London district.

The total number employed in November, 1915, was 39, of whom 22 were men. In 1916 the weekly average of employees was 360, in 1917, 450. Originally these were drawn from the surrounding districts, in competition with the other industries of Hertfordshire and Middlesex. Dilution eased the situation in 1916 and 1917. By the end of 1916 the women employed were 236 and men 110, and in the following March women replaced men on trolley work. Canteens, clubs, and a crèche were organised for the two factories. In the spring of 1917 the female labour of the district was exhausted, and railway fares up to 3s. weekly were allowed to overseers from outlying districts. In September, 1917, workers were brought in from Norwich. The establishment of the Greenford chemical shell factory drew away workers, and in March, 1918, the number of employees at both factories was only 30 per cent. of that needed. The situation was again met by importing labour from the provinces.

The expenditure on the original buildings was estimated in February, 1916, at £15,000. By the end of 1917 the estimate was raised to £40,487, and the actual outlay on land, buildings and plant, down to 31 March, 1918, was £40,306.

Trench Warfare Filling Factory, Watford No. 2.

This factory was built for filling heavy trench mortar ammunition early in 1916. It occupied about 40 acres of agricultural land, taken under the Defence of the Realm Act, at "Callowland," Bushey Mill Lane, Watford. Sites had previously been examined at the Sabulite Factory, Ware, and at Reading. A preliminary scheme for transporting the explosive direct from the Watford ammonal factory was abandoned, in view of its cost, in favour of an extension of the sidings at Watford No. 1. When an amatol bursting charge was substituted for ammonal, it was still arranged that mixing should take place at the explosives factory and not at the place of filling, as was the normal arrangement in shell-filling factories.

Constructional work was carried out under the Office of Works, by contract on a lump sum basis. The site was surveyed on 22 January, 1916, building began on 19 February, and 26 filling sheds were finished by the end of March. The completion of water supply and sanitary arrangements was delayed till June. A magazine, with a capacity of 250 to 300 tons, was built in that month.

The factory was controlled directly by the Trench Warfare Supply Department, and was under the same management as Watford No. 1 (*q.v.*). It was laid out for filling 20,000 bombs weekly, and in April, 1917, was extended to deal with 25,000. Since the filling programme for 9·45-in. bombs never reached the number anticipated the capacity of the factory was otherwise occupied. In addition to undertaking

the entire 9·45-in. filling programme, upon which work began at the end of May, 1916, the factory filled and assembled trench mortar fuses from June, 1916, onwards, and also fermanganised the cast-iron fuse-bodies upon special plant, completed in October, 1916. The assembling of aerial bombs began in mid-June, 1916, and in the following January the actual filling of these bombs was undertaken. In April, 1917, a scheme was started for assembling chemical artillery shell, in order to avoid erecting a special building for the purpose. The factory concentrated upon this work during a period of urgency in the early summer of 1917, but these operations ceased with the extension of the Greenford Chemical Shell Factory. From March, 1917, onwards gaines for the Livens projector drums were filled in large quantities, both for British and American use. The loading of Pippin rifle grenades began in the following May, 1917, and about 340,000 of these were filled here. In May, 1917, the work of the factory was reduced by 50 per cent., pending a decision as to its continued use for assembling chemical shell. Almost every class of work undertaken was again increased in the following July.

The labour conditions resembled those at Watford No. 1 (*q.v.*). The capital expenditure was estimated in February, 1916, at £65,000; in December, 1917, at £86,965. The actual capital cost, including land, buildings and plant, down to 31 March, 1918, was £99,050.

IV. Individual Factories for the Filling and Assembling of Chemical Shell.

National Filling Factory, No. 23, Chittening.[1]

The demand for shell filled with mustard gas (H.S.) was first made about September, 1917. The Ministry then entered into an agreement with Nobel's Explosives Company, Ltd., under which the latter were to design and run a factory for the manufacture of H.S. by the thio-glycol method and for the charging and filling of the shell. The lay-out was undertaken in November, 1917, the site selected at Chittening, and construction began under contract with Messrs. Thorburn in January, 1918. During the spring of 1918 arrangements for H.S. production were greatly extended, and the control of poison gas manufacture and its charging into shell ceased to be united in one authority. To avoid dual responsibility in a single factory the work of charging and head-filling was undertaken at Chittening while manufacture was transferred to Avonmouth.[2] Under the new arrangements the Chittening factory was to be controlled directly by the Controller of Gun Ammunition Filling, and, after negotiation with Messrs. Nobel's, the construction contract was accordingly transferred to the Ministry, who appointed a director to supervise its completion.

The site consisted of some 200 acres of lowlying level ground bounded on the south and west by the Great Western Railway, and on the north by the main road to Bristol, and construction

[1] C.R./Filling/297, 319, 324, 377, 379; HIST. REC./R/1340/33, 34; HIST. REC./R/1122.3/40.

[2] See above, p. 49.

was pressed on with speed. H.S. was a dangerous liquid producing serious physiological and psychological effects on workers who were either touched with the liquid or inhaled the vapour given off by it. The peculiar difficulties involved in dealing with such a material gave rise to serious problems as to plant and ventilation, but, owing to the urgency of the demand, attention was concentrated on output, and arrangements were made to start on emergency lines, before complete provision was made for the safe and efficient handling of the liquid and for the destruction of exposed H.S., whether in the form of spills or leakages of liquid or of escaped vapour. The period of production was thus divided into three stages :—(1) That in which Nobel's charging machines were used without mechanical ventilation to destroy fumes ; (2) when a system of fan ventilation protected workers inside the charging rooms at the expense of those outside ; and (3) when new and adequate machines and ventilation were installed. The factory was laid out for charging and filling 52,000 6-in. shells, 34,000 4·5-in. and 100,000 18-pdr., but work was actually carried on only with 6-in. shell. Fourteen units were set up to charge the liquid into the shells, which were then passed on to be filled with the bursting charge of fumyl. Except for a small regular delivery from Messrs. Levinstein, of Manchester, the whole of the H.S. was conveyed from Avonmouth in tank wagons.

The first consignment came from Messrs. Levinstein about the end of June, 1918, and experimental charging was immediately begun at Chittening. In July supplies began to arrive from Avonmouth, and it was feared that charging would not keep pace with the production of H.S., but by 14 July 1,000 6-in. shells had been charged and all the available H.S. used. During the week ending 26 July 10,920 lbs. of H.S. were received and dealt with, improvements to the ventilation were planned, and it was decided to instal vacuum machines in place of the gravity type designed by Nobel's. Owing to the urgent need of immediate output on an extremely large scale, work began as construction proceeded, but was frequently suspended owing to the shortage and inferior quality of the H.S. Thus from 28 July the factory was held up for a fortnight, and again in August 15 machines, capable of charging 3,000 6-in. shell per day, were standing idle. By 29 August three units were at work, the output for July and August being 3,801 and 3,835 shells respectively. The output increased with the improvements gradually evolved, and in September 18,215 shells were charged, while in October, when the first vacuum machines were set up, output rose to 59,573. By this time charging was well ahead of gas production. Early in November the factory was again idle, owing to serious difficulties at Avonmouth which cut off the supply of H.S., and after the Armistice all chemical charging was abandoned. The total number of shells filled up to the end of 1918 was 86,400.

Some of the most difficult problems encountered by the management were connected with the question of labour, as the need for protection against the harmful effects of the gas and the treatment of workers affected were matters requiring the closest attention. Owing to the urgent demands of the service, practically all other considera-

tions were sacrificed to output, with the result that work was carried on under very bad conditions. The whole work of charging being new, difficulties had to be solved almost entirely from experience, which was not obtained without ill effects on the workers. While construction was still in progress and the welfare arrangements were scarcely yet established, temporary plant was set up, and consequently, although for so dangerous a process operatives needed to be unusually well trained, the majority were incapacitated as soon as the training was completed. In spite of the many efforts perpetually made by the authorities to ensure protection, at one time workers actually engaged on charging had nearly 100 per cent. casualties, while for a considerable period one casualty was reported for every six to nine shells that left the factory. Workers on head filling also became infected by the charged shell which were splashed, but the worst effects were felt by the fitters who had to work on contaminated machines. For most of the summer all medical and welfare work was carried on in improvised buildings intended for other purposes, the elaborate surgery being completed after the Armistice. Experience proved that healthy girls were more resistant than many of the available men, who were generally less fit, and practically all the charging was done by female labour. Owing to the irregularity of H.S. supplies night shifts had to be worked to make up for time lost when no gas was delivered. On 19 August, 1918, 230 women, 210 men and 110 skilled trade staff were at work, but it was calculated that to reach the estimated output, the unskilled labour would have to be increased to 1,000, exclusive of the replacement of casualties.

The actual capital expenditure, 31 March, 1919, amounted to £57,900.

The Chemical Shell Assembling Station, Greenford.[1]

When in the spring of 1916, the use of lethal artillery shell was approved, it was at first decided to assemble the charged shells with their bursters, either in the National Filling Factories for H.E. shell, or at the Royal Laboratory, Woolwich, in order to make use of factories accustomed to the handling of explosives. The first instalments of lethal shell were accordingly assembled at Woolwich, but actual experience with leaky shells emphasised the risks of handling projectiles filled with chemicals, and it was arranged that a separate assembling station should be established by the Chemical Warfare Section of the Trench Warfare Supply Department.

The factory was located at Greenford, Middlesex. The site, which was agricultural land, leased by the Purax Company from the Ecclesiastical Commissioners, was taken under the Defence of the Realm Act, and structural work was undertaken by the Office of Works. Construction began in August, 1916, and the initial project was completed in the following February. In March, 1917, arrangements were made to double the capacity in order to meet the increased demand for chemical shells. The factory was administered by a superintendent, under the direct control of the Chemical Section of the Trench Warfare Supply Department, until the spring of 1918, when

[1] HIST. REC./H/1690/9 ; T.W.5923.

its administration was transferred to the Controller of Gun Ammunition Filling.

Operations began in January, 1917, and the factory was thenceforward responsible for assembling practically the whole of the output of lethal shells until a part of this work was undertaken by the National Filling Factories and by Chittening in 1918. Facilities were provided for experimental work, and labour-saving devices were installed during the spring of 1917.

Considerable difficulty was experienced in obtaining operatives. When the factory started up in the first week of January, 1917, there were 590 workers on the books ; a year later there were over 1,000. Special arrangements were made for the transport of workers, and at one time volunteers were brought from the Trench Warfare Filling Factory at Erith, where work was being reduced.

The capital expenditure on the factory to the end of March, 1918, was £109,900.

H.M. Factory, Walthamstow.[1]

The national factory for charging and assembling chemical projectiles at Black Horse Lane, Walthamstow, was originally erected by contractors, Messrs. Baird and Tatlock, in July and August, 1915. They then undertook to charge and assemble lachrymatory grenades in the new factory, which they set up on waste land next their " Duroglass " works, where the glass containers for the chemicals were being made. In March, 1916, extensions were made to enable the factory to charge and assemble lachrymatory shell, for which purpose skilled labour had been retained at the factory during the previous winter. Progress was not entirely satisfactory, and the works were nationalised under an agency agreement as from the week ending 10 June, 1916. In November, 1917, direct control over the factory was taken by the Chemical Section of the Trench Warfare Supply Department.

The factory was engaged in charging and assembling various types of lachrymatory grenades from August, 1915, onwards. In February and March, 1916, respectively, work began upon charging and assembling 4·5-in. and 60-pdr. lachrymatory shells. Thenceforward the main work done was the assembling of various classes of lachrymatory shells, and special arrangements were made in July, 1917, for charging 6-in. lachrymatory shells. When the use of chemical grenades was revived in 1917, the factory resumed the charging and assembling of these grenades. It also undertook a considerable amount of salvage work in the summer of 1918, emptying lethal trench mortar bombs and re-charging the mixture into Livens projector drums.

Special precautions were taken to lessen the risks from lachrymatory liquids, and medical attendance was provided. The workers averaged 250 weekly during 1917, and were mostly women. A special staff of women was maintained to deal with transport, since the factory was situated about a mile from the nearest railway station. Much of the building work in connection with extensions, such as stores and experimental plant, was effected by the employees in the factory.

The total capital expenditure to March, 1919, was £9,900.

[1] T.W./Contract/351, 1594, 1881 ; Hist. Rec./H/1122.7/13.

CHAPTER VI.

GOVERNMENT FACTORIES FOR CARTRIDGES AND SMALL ARMS AMMUNITION.

I. Introduction.

(*a*) *The Government Cartridge Factories.*[1]

By far the most important of the national factories which were established for processes connected with the production of small arms ammunition were the Government Cartridge Factories initiated in the spring of 1916 to meet increased requirements. Early in the year the demand was raised to 150,000,000 cartridges weekly, and as existing organisations were already developed to their utmost ability, State manufacture was practically essential to cope with the new programme. Plans were accordingly made to provide for a weekly output of 30,000,000 rounds of ·303-in. Mark VII from State factories. One of these, to produce 6,000,000 rounds, was established at Woolwich under the control of the Chief Superintendent of Ordnance Factories, and its history belongs to that of the Arsenal,[2] but the others were operated as agency factories by various cartridge-making firms.

Negotiations began in March, 1916, with the heads of firms, and three companies undertook to manage factories in the neighbourhood of their own works. The Birmingham Metal and Munitions Company agreed to manage works at Blackheath, Staffs., known as G.C.F.1, for 12,000,000 rounds ; the King's Norton Metal Company undertook a second at Blackpole, which became G.C.F.3, and Messrs. Eley Brothers erected G.C.F.4 on ground adjoining their own works at Edmonton, in North London. These two, and the Woolwich factory, undertook 6,000,000 rounds apiece. The Woolwich factory was known as G.C.F.2.

The management agreements made with the three firms were identical in each case as regards the broad outlines, though specific details varied according to circumstances. The companies, acting as agents for the Ministry, purchased the necessary land and erected and equipped the factories, receiving as remuneration a fixed percentage of the cost of construction. The plant remained the property of the Ministry, from, or through, whom all materials were to be bought, and the Ministry might alter the type of ammunition to be made, paying any cost involved in the change. All cost of production was borne by the Ministry, and the firms received a management fee covering the wages of all employees above and including the rank of foreman, and a bonus on

[1] *See* also Vol. XI, Part VI.

[2] *See* above, Chap. I.

economical working which varied with the price of materials and the rate of wages. The companies appointed and trained the necessary staff, and were not to be held responsible for delays or reductions in output due to causes beyond their control. The Ministry might at any time give notice to terminate the agreement on payment of compensation. After the war the firms were to be entitled, and under certain conditions bound, to continue as managers if the Government required their services; they were also to have the option within a certain period of purchasing land, buildings and machinery at 5 per cent. less than any other offer, if the Ministry wished to sell. The formal agreements were not signed until May and June, 1917, but construction began in the spring of 1916. In July, 1916, while erection was proceeding the small arms ammunition programme was revised and it was decided, in view of Russian requirements, that the capacity of the new factories should be halved and that they should produce 15,000,000 rounds of 7·62 mm. ammunition instead of the ·303-in. originally intended. This involved alterations in plant and delayed the equipment of all the factories except Messrs. Eley's at Edmonton, which was not sufficiently advanced to be affected. In January, 1917, as part of a general reduction in the programme, the output originally planned was reduced by half in each case, and in May, 1917, the firms opened negotiations with a view to amending the financial clauses in the agreement, which these subsequent changes in programme had rendered less favourable to them.

Possession of suitable sites had been taken under the Defence of the Realm Act in the summer of 1916, and construction began immediately. Constructional work was somewhat delayed by the severity of the winter and by difficulties in getting machines and labour. The first of the four factories began operations before the end of 1916. Cups were supplied by the Government Rolling Mills, Southampton, and after initial difficulties were overcome two of the three agency factories exceeded their estimated output in 1917. In 1918, these two factories and the Woolwich factory were changed over to the manufacture of ·303-in. cartridges, and by July the two agency factories were producing between them more than the 15,000,000 rounds formerly allocated among the four factories. The third agency factory was taken over by the Air Board for aero-engine repair work.

The factories were all confronted with similar difficulties, particularly the failure or delays of building and machinery contractors and the scarcity of labour. All were situated in towns where competition for labour was intense, but the peculiar advantages enjoyed by the state factories in the way of building and plant enabled them to effect dilution to a greater extent than any trade firm. The proportion of skilled labour to the whole was, on an average 9 per cent., and women formed a large part of the unskilled labour. At the end of 1917, when the employees in the three factories numbered 5,900, the percentage of female labour was 40·4; in October, 1918, when two factories only were working, there were 6,700 workers and 5,500 (81·5 per cent.) were women.

The original estimate sanctioned by the Treasury for the four factories was £1,539,000, including the £26,000 which was required for the acquisition of land for the three agency factories. The actual capital expenditure on the three agency factories to 31 March, 1918, amounted to approximately £966,000, while about £231,300 was expended on Woolwich.[1]

(*b*) *Miscellaneous Factories for Processes connected with Small Arms Ammunition.*

Detailed accounts are given below of two other national factories which were established in connexion with the supply of small arms ammunition. These were the Coundon Factory for filling a special type of bullet, and the Government Mills at Southampton, which were set up for the rolling of brass and cupro-nickel strip.

Two other establishments were directly controlled by the Non-Ferrous Metals Department of the Ministry during the year 1918. The one was a manufacturing warehouse at No. 50, Porter Street, Sheffield, which was originally engaged upon manufacturing processes in connexion with cupro-nickel ingots for small arms ammunition and also with brass discs for quick firing gun ammunition. With the reduction in the small arms ammunition programme early in 1918, manufacture ceased at these premises, but they were utilized as a store and also as offices for a casting shop. This was a shop originally owned by Messrs. Kent Smith, Ltd., in Bacon Lane, Sheffield. It was taken over by the Ministry as from 15 April, 1918, with a view to improving the general supervision and management. The shop was engaged in making bullets out of specially treated strip-metal by a novel electrical process. It was finally closed down in the summer of 1919. In the meantime, the premises in Porter Street had again been used, when the small arms ammunition programme was increased in September, 1918. They were then reorganised for cropping and inspecting cupro-nickel ingots.[2] By March, 1918, the capital expenditure on the premises in Porter Street amounted to £731, and on the casting shop to £1,200.

II. Individual Government Cartridge Factories.

Blackheath Government Cartridge Factory—G.C.F.1. (Birmingham Metal & Munitions Company).[3]

On the establishment of the Government Cartridge Factories early in 1916, the Birmingham Metal and Munitions Company undertook to manage a factory for the production of 12,000,000 rounds of ·303-in. Mark VII weekly. An agreement was drawn up on the lines common

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[1] The figure given for Woolwich is to 31 December, 1917, the latest available.
[2] D.F.2/N.F./K/14,18.
[3] HIST. REC./H/1440/3; HIST. REC./R/400/57; D.D.G.E./E.M.2/1363, 1218, 1891, 882, 1429, 1542, 1048, 1601, 1579.

to the three new cartridge factories, and in accordance with the change of programme of 1916-17 the firm agreed to manufacture 6,000,000 a week of 7·62 mm.

A site was found for the factory at Blackheath, Staffs., most of which was owned by Sir Charles Holcroft. Before June, 1916, possession was taken under the Defence of the Realm Act, and subsequently the total purchase price for the site, including compensation to tenants, was estimated at £10,000. Instructions to proceed with arrangements had been given to the company in March, 1916, and the buildings were considerably ahead of the other two factories, being sufficiently forward for two units of machinery to be installed by December, 1916, though some difficulty was experienced in obtaining water power and light. Special pumping arrangements had to be made for water supply, and the electric power obtained from the local supply company was not very satisfactory. Much of the machinery was supplied by Messrs. Greenwood & Batley, who had a large order for the Russian Government for plant which could not be shipped across during the winter, and was accordingly diverted to the Government Cartridge Factories. Operations began at Blackheath before Christmas, 1916, although the factory was held up in December by lack of cups, due partly to a shortage of copper, and partly to delays in submitting designs. By February, 1917, four units were practically in position, though delay was caused by the non-appearance of loading machines, which were not completely delivered until December, 1917. Difficulties also developed in making a satisfactory bullet, and when these were overcome others arose in the necking process of the case, so that in October, 1917, bullets were 5 or 6 millions ahead of cases. Output of the Russian ammunition therefore, rose very slowly, and though it had been estimated that the maximum would be reached in October, the actual deliveries did not then reach 5,000,000 weekly. In November, 1917, however, the output averaged 6,176,500, the highest delivery attained by the factory in this type of ammunition. In February, 1918, the factory changed over to ·303-in. at the rate of 4,000,000 weekly, and it was laid down that further deliveries of 7·62 mm. should not exceed a total of 14,000,000. To economise material an interchange of 7·62 mm. components was arranged with Messrs. Kynochs, to balance cases and bullets. From April, 1918, a special effort was made to increase the ·303-in. output which reached 7,000,000 weekly in August, though rejections on inspection amounted to 10 per cent. Futher projects brought forward to increase the output to 9,000,000 did not materialise before the Armistice, after which production of new ammunition ceased entirely by 14 December, only 9,916,159 having been delivered since 20 November. Rectification of rejected ammunition continued till the end of the month, and in 1919 the factory was taken over by the Central Stores Department.

Dilution of labour was not carried out so extensively as at Blackpole, though the factory compared well in this respect with any trade firm. The proportion of skilled men employed in 1917 was 10 per cent., while in the tool room 63 per cent. were women and boys.

Throughout the summer of 1918 there was an urgent demand for labour, and in October, 1918, 3,491 workers were employed, of whom 3,026 (86·7 per cent.) were women. When the agreement was drawn up the estimated cost of construction was £330,000. By March, 1917, this was raised to £380,000, exclusive of the architects' fee and the fee payable to the agents, which amounted to about £21,400. The actual capital expenditure by 31 March, 1918, was £392,000.

Blackpole Government Cartridge Factory—G.C.F.3. (King's Norton Metal Company).[1]

In March, 1916, the King's Norton Metal Company undertook to manage a factory at Blackpole, Worcestershire, for the production of 6,000,000 ·303-in. Mark VII a week.

The site selected at Blackpole covered 67¼ acres, of which 51 were owned by Wall's trustees, and the rest by Lord Hindlip. Possession was taken under the Defence of the Realm Regulations, and in August, 1916, £7,000 was paid as a fair purchase price for the property. A neighbouring canal afforded water supplies, and power and light were obtainable from the local company. The buildings at Blackpole were practically complete by February, 1917, and production began at the end of the month.

In accordance with the revised programme the factory undertook to produce 3,000,000 rounds of 7·62 mm. ammunition a week, and in June, 1917, the actual output was nearly 2,000,000, which was not only an exceptionally good output as regards quantity, but excellent in quality, there being no rejections by the Inspection Department from the first large delivery. Though the factory started production considerably later than the first Government Cartridge Factory, it reached its full output much more quickly, as by October, 1917, it was producing the allotted 3,000,000 weekly, working only on a day shift. In December, the output of 7·62 mm. from all factories was reduced and at the beginning of this month Blackpole began making ·303-in. By the end of the year production of 7·62-mm. had ceased in this factory, though the last consignment did not pass inspection until February, 1918. In January, 1918, ·303-in. bullets and cases were produced separately at the rate of 3,000,000 weekly but difficulty was experienced in loading, until in February a partial night shift was put on to work off accumulation. This resulted in a delivery of 3,500,000 almost at once. At the end of February, 1918, the maximum was raised to 4,000,000 and the factory was speeded up to its utmost capacity on day and night work, till the weekly output reached 9,000,000 by 29 July, and the total amount of ·303-in. delivered up to 24 August, 1918, was 192,418,550. After the Armistice three months notice was given to the factories to close down, and instructions were issued that no more virgin copper, spelter or nickel should be used. A gradual decrease in output followed during the rest of the year.

[1] HIST. REC./H/1440/3; HIST. REC./R/400/57; D.D.G.E./E.M.2/882, 1363, 1077, 1218, 1429, 1114, 1430, 1863, 1721.

The good output from this factory was largely due to its excellent management, which was most satisfactory throughout its history. There were few changes on the staff, careful organisation by the authorities and good co-operation on the part of the employees, while the bullets turned out were considered " some of the best in the trade."

Dilution of labour was carried out to the full. In May, 1917, 4 per cent. of the employees were skilled men and 82 per cent. women and boys, while in October, 1918, of 3,235 employees, 2,462 (76·1 per cent.) were women. In the toolroom 78 per cent. of the work was done by women and boys, though at first the skilled toolroom men were opposed to female labour. In April, 1918, the factory was sending out urgent demands for labour to provide the great increase required in production.

In the spring of 1916, the estimated cost of the factory was £227,000. The change over from Russian ammunition to ·303-in. involved an expenditure of £5,000, and in January, 1918, a fresh estimate amounted to £284,122 including the £7,000 paid for the land. The actual capital expenditure to 31 March was £289,800.

Edmonton Government Cartridge Factory—G.C.F.4. (Messrs. Eley Brothers).[1]

In the spring of 1916, Messrs. Eley Brothers undertook to erect and manage a factory at Edmonton in accordance with the new scheme for Government Cartridge Factories. An agreement was drawn up, as for the other factories similarly established,[2] but a special clause was added in this case, in view of the firm's position with regard to their existing contracts. Messrs. Eley were producing 2,000,000 cartridges weekly in their own factory on plant paid for by a Government advance, not yet fully repaid. They then paid up the balance of this loan, becoming owners of the plant, which was purchased by the Ministry for the new factory. All the firm's small arms ammunition manufacture was thus to be concentrated in the government factory as soon as it was ready, the standing contract with the firm being cancelled. It was also agreed that the Ministry should buy certain materials from the firm.

An area of 13 acres adjoining the company's own works, and owned by the Great Eastern Railway Company and others, was selected as a site for the factory. Possession was taken before June, 1916, under the Defence of the Realm Act, and the property was subsequently valued at £9,000. There was considerable delay in the erection of the factory. Construction did not begin until August, 1916, and was hampered by various occurrences, including air-raids, so that by February, 1917, installation of machinery was only just begun. Under the revised programme of January, 1917, the factory undertook 3,000,000 weekly of 7·62-mm. ammunition, but work had not been entirely transferred

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[1] HIST. REC./H/1440/3 ; D.D.G.E./E.M.2/1218, 1363, 882, 1081, 1622, 813, 1429, 1430, 1781.

[2] *See* above p. 185.

to the government factory even by December, 1917, when the combined output from the old and new factories only averaged 1,788,000 weekly, though the quality was good. The managers hoped to reach the maximum in January, 1918, and the rounds accepted by the Inspection Department in February and March numbered 23,415,225, a figure which gives a weekly average of over 2,900,000. Early in 1918 the requirements of 7·62-mm. dropped, and while the other Government Cartridge Factories turned over to ·303-in. ammunition, the Edmonton factory ceased production entirely at the end of March, and was taken over by the Air Board for aero-engine repair work.

The factory had comparatively little difficulty in obtaining labour. The proportion of skilled labour was 14 per cent. of the whole, but the management was hampered in diluting toolroom labour by an agreement made by Messrs. Eley with the Amalgamated Society of Engineers that women should only be employed there on repetition work. In January, 1918, however, there were 1,493 employees, and the women numbered 1,161, 77·8 per cent. of the whole.

In December, 1917, the estimated capital expenditure was £302,976. The total capital expenditure on the factory up to 31 March, 1918, was £284,200.

III. The National Small Arms Ammunition Factory, Coundon (Coventry).[1]

In the summer of 1917 when, among various special types of ammunition, the R.T.S. incendiary bullet was developed to meet the requirements of the Royal Flying Corps, Machine Gun Corps and Home Defence, the Ministry decided to establish a special national factory at Coundon, near Coventry, to deal with the filling of this ammunition. As the chief considerations were great secrecy and immediate output, it was necessary to have a factory entirely under government control, and if possible to utilize existing premises. Certain buildings on land belonging to Mr. J. F. Buckingham were, therefore, purchased and extended, and the surrounding land, belonging to the Coventry Corporation, was also acquired under the Defence of the Realm Act, though as this was to be used after the war for municipal purposes, only temporary buildings were erected there. Some land originally taken was later released for purposes of food production.

The factory was administered, under the Department, by a manager, Mr. Buckingham himself acting in this capacity during the early stages of experimental production.

Partly owing to the uncertainty as to whether the efficiency of the bullet would justify its production in bulk and partly to the urgency of the demand, all the early constructional work was of a temporary nature rapidly completed. On 21 July, 1917, the manager was instructed to proceed with the necessary constructional operations, and these advanced so rapidly that production was possible in September. The Air Board asked for supplies of R.T.S. bullets in August, 1917,

[1] Vol. XI, Part VI, Chap. VI ; HIST. REC./R/400/57 ; D.D.G.E./E.M.2/529, 1157, 1149.

and at the end of September, after some experimental work, the factory was instructed to proceed with the manufacture of 10,000 rounds. The first large output of 1,900 was delivered by 17 November, 1917, and in spite of a temporary delay due to a strike at Coventry, the 10,000 cartridges were completed in December, 1917. The Flying Corps reports on the quality of the ammunition being favourable, fresh construction was then begun to make the factory buildings more permanent and convenient. Production continued throughout 1918, rising from a weekly average of roughly 4,000 in January, to about 20,000 in March, while by June the estimated weekly delivery of 200,000 was made. This rate was usually maintained until the Armistice, after which production was maintained on a much smaller scale, 11 workers being employed in April, 1919, on a monthly output of 5,000 R.T.S. cartridges and on breaking down scrap bullets. On 6 September, 1919, manufacture ceased and a small amount of experimental work was transferred to the Enfield Small Arms Factory.

As the Coundon factory was only designed to meet the demand for R.T.S. ammunition which was comparatively small, it was planned on very limited lines. The estimated cost was between £5,000 and £7,000, and by March, 1918, when the factory was in full swing only 10 men and 66 women were employed. The capital expenditure to March, 1918, was £5,400, but additional expenditure was incurred during 1918 on constructional work, and by March, 1919, the total amount was £12,600.

IV. The Government Rolling Mills, Southampton.[1]

The establishment of the Government Rolling Mills for the production of brass and cupro-nickel strip followed as a result of the increased output of small arms ammunition sanctioned in the spring of 1916. For some time rejections of ·303-in. cartridges had occurred owing to the inferior quality of brass used, while the supply of cupro-nickel was falling short of the requirements even under the old small arms ammunition programme. When, therefore, the output of ammunition was raised in February, 1916, from 400,000,000 to 500,000,000 and later to 550,000,000 per month, increased supplies of metal were essential. By March, 1916, the scheme for a central government factory was sanctioned as being probably more effective than the alternative plan of extending existing plant in various factories. It was expected to economise labour, to avoid the difficulties due to the inferior and varying qualities of metal produced by small makers, to be able to make use of salvaged ammunition and finally to be a saleable commercial undertaking after the war.

Southampton was considered a suitable town in which to set up the mills, as it formed the delivery port for much of the raw material, possessed excellent transport facilities by land and water, and afforded a good labour field. With regard to the use of the mills after the war, a feature constantly kept in view during the design, the geographical

[1] HIST. REC./H/1122.9/1 ; D.D.G.M. 057 ; Sec./Gen./709 ; M./Demob./68. For a further account of these mills, see Vol. XI, Part VI, Chap. VIII.

situation at Southampton was favourable for competition with the German export trade. The site selected was Weston Park, the property of the London and South-Western Railway Company, which lay at the junction of the River Itchen and Southampton Water. A branch line could easily connect the factory with the company's main line, which passed less than a mile away. 92 acres were taken over under the Defence of the Realm Act, and construction began in April, 1916.

An agreement was made at the end of March, 1916, with Mr. G. H. Robinson, a consulting engineer, thoroughly conversant with the German methods of casting and rolling. He undertook to superintend the lay-out, erection and equipment of the mills, and to manage them when ready for production. He was to receive £100 per month, and 1 per cent. on the cost of building and plant up to £5,000, and 5 per cent. on the first £100,000 saved by the factory over the usual market price of cups, with a minimum remuneration of £5,000 payable should hostilities end before construction was complete.

The factory was planned on an exceedingly large scale, to produce strip for 42,000,000 brass cups and an equal number of cupro-nickel cups per week, working day and night-shifts, a capacity four times as great as that of any other British mill. The cupping plant was included in the equipment, thus avoiding the transport and depreciation by dirt of the scrap which amounted to 40 per cent. of the total metal. The primary consideration in the lay-out of the factory was rapid and economical production, and the plant was designed to eliminate all unnecessary handling of materials and lessen the possibility of congestion. The factory had its own power-station and also gas-works, as special gas-fired melting furnaces, capable of greater heat than usual, were installed.

Production began at the end of February, 1917, and although for a time difficulty was experienced in the annealing plant, by the end of March about 5,000,000 Mark III Russian cups were being sent each week to the Government Cartridge Factories. In April, the output of fuse-stampings was delayed owing to the failure to secure deliveries of the lead required, and the managers made use of all the construction lead on the site. By the summer, the mills were working smoothly, and in November, 1917, the output of brass cups exceeded the estimated capacity on a day-shift, while the strip was considered to be of the highest quality. In 1918, production continued steadily in proportion to the requirements of the cartridge factories.

Of the labour employed in the Rolling Mills in October, 1918 (2,109), 753, or 35·7 per cent., were women. The greater number of these were discharged within a few weeks of the Armistice, as the manufacture of strip was stopped at once. Pending the decision of the Ministry as to the ultimate disposal of the factory, part of the plant was used for smelting non-ferrous scrap.

The estimated cost of buildings and machinery was £673,956, but by March, 1918, the capital expenditure was £1,089,900. Including the cost of land, the total expenditure on the factory to the end of 1918, amounted to some £1,200,000. The cost of production ranged from about £14 to £16 per ton, as compared with the trade price of £15 to £17.

CHAPTER VII.

NATIONAL ORDNANCE FACTORIES.

I. Introduction.[1]

Gun manufacture was undertaken at four National Ordnance Factories, three of which were originally used for other purposes, and turned over to gun work in 1917. The factories ultimately classed as National Ordnance Factories, and administered by the Gun Manufacture Department, were as follows :—

Name of Factory.	Purpose and Administration.	References in other Chapters.
Leeds	Taken over for shell manufacture by the Leeds Board of Management and managed by them. Classed as a National Projectile Factory, 1915–1917 ; National Ordnance Factory, 1917–1918.	p. 105
Nottingham ..	Erected by Messrs. Cammell Laird for shell manufacture and managed by them as a National Projectile Factory, 1915–1917 ; and as a National Ordnance Factory, 1917–1918.	p. 142
Sheffield	Erected by Messrs. Hadfield for shell manufacture and managed by them as a National Projectile Factory, 1915–1917 ; as a National Ordnance Factory, 1917–1918.	p. 146
New Basford ..	Taken over in 1917 for gun manufacture and managed by Coventry Ordnance Works as a National Ordnance Factory.	

A brief account of the Basford factory is given below, but the detailed history of the factories which originally made shell is related elsewhere. Another shell factory occasionally called a National Ordnance Factory since it made and repaired guns, was that at Ponders End, which came under the control of the Gun Ammunition Department, as a National Projectile Factory, in the last week of the war.[2] A factory engaged only on repair, the National Gun Carriage Repair Factory at Southampton, was administered by the Gun Manufacture Department, but its history belongs elsewhere.[3]

In the spring of 1917, the problem of gun repair was particularly urgent ; guns in the field were wearing out faster than they could be replaced ; and more ammunition was being produced than could be fired. It was, therefore, decided to convert some of the shell capacity

[1] Vol. X, Part I; Hist. Rec./R/1122/20 ; C.G.M. 387/2, 3 ; C.G.M. 387Q ; (Printed) *Weekly Report*, 1918, *passim*

[2] *See* above p. 125.

[3] *See* below p. 217.

at National Projectile Factories to gun repair, and among the factories where part of the plant was turned over were Messrs. Cammell Laird's factory at Nottingham, Messrs Hadfield's factory at Sheffield, and the Hunslet Shell Factory at Leeds. Nottingham and Leeds undertook 18-pdr. guns, and Sheffield 60-pdrs. All three began by re-lining guns, in addition to their shell work, but in a few months' time they were asked to undertake manufacture also, and by the end of the year all three had definitely turned from shell to gun work, and were thenceforward classed as National Ordnance Factories, their local administration remaining the same as before. The Hunslet factory at Leeds formed one of a group of factories managed by the Leeds Board of Management, but classed as National Projectile Factories for headquarters purposes, and when Hunslet ceased shell work the whole group was administered as National Ordnance Factories, though only one factory besides Hunslet did any gun work.

With the exception of Basford, little construction or alteration of buildings was necessary in connection with the National Ordnance Factories. At Leeds, a carriage erection shop was under construction in 1918, but was not completed at the time of the Armistice, the delay being largely due to lack of structural materials.

The Sheffield factory continued the repair and manufacture of 60-pdrs. until the end of the war, the only other gun work undertaken being the rifling of 8-in. howitzers. Leeds was mainly engaged on 18-pdrs., though 60-pdr. guns, 6-in., 8-in. and 9·2-in. howitzers were rifled and recuperator liners for 6-in. and 8-in. howitzers were manufactured there. Nottingham began with 18-pdrs., but early in 1918 the plant was converted for the new type of 6-in. gun. This factory was particularly well laid out, and its output was most valuable.

While repair work only was undertaken, some difficulty was experienced owing to the inconstant supply of guns for repair, but when manufacture began the factories were able to work the two programmes together and thus keep their capacity occupied.

A trouble from which all the factories suffered, more or less, was lack of skilled labour. At Nottingham, in August and September, 1918, the shortage of planers and turners was reported to be seriously holding up manufacture, and a similar lack of skilled men at Basford delayed development throughout the summer of 1918. At Leeds, in March, 1918, a strike occurred, owing to the alleged wrongful dismissal of four men, and all the factories were idle for some days. Some trouble was also experienced at Leeds with regard to dilution. Owing to the heavy nature of gun work, female labour could not be employed on a large scale. The only one of the factories which employed no women was Sheffield. The highest proportion of female labour was at Nottingham (1,366 out of 2,758 in April, 1918). At the time of the Armistice, out of approximately 5,700 employees at Nottingham, Sheffield, Leeds[1] and Basford, 22·8 per cent. were women.

[1] The figure for Leeds (1750; women 22·7 per cent.) is for Hunslet only. At the other factories, Newlay, Armley Road, and the fuse factories, there were 5,580 employees, 62·9 per cent. being women.

II. New Basford National Ordnance Factory.[1]

Towards the end of 1917 it was decided that a new type of automatic gun—the 37-mm. (1½-pdr.)—which had been developed by the Coventry Ordnance Works, should be provided in large numbers for the Air Force. The extensions necessary for manufacture on a large scale could not be undertaken at Coventry, and in December, 1917, a factory at New Basford, on the outskirts of Nottingham, was taken over under the Defence of the Realm Act. The factory, which occupied a floor space of about 40,000 square feet, was in use when taken over for the storage of machinery, and for lace manufacture. It was strongly built, but was old, rather dark, and badly ventilated, and considerable alterations were required. It was also some distance from a railway siding, though conveniently situated for the transit of workpeople. The factory was managed by the Coventry Ordnance Works as from 14 February, 1918, but the management agreement was not signed until June, 1919. The maximum output contemplated was 20 guns a week. Raw material was provided by the Ministry, who were responsible for all working costs. The firm received no management fee, but it was arranged that they should be paid royalties at the rate of £20 per gun for the first 500 guns manufactured (at Basford or elsewhere) and £10 per gun thereafter. Royalties amounting to £5,000 were also paid to the original designer of the gun.

The work of dismantling the old factory began at the end of 1917, and the installation of new plant started in February, 1918. Delays occurred in the delivery of machinery, but manufacture began in May. The first two guns were not completed till the second week of October, so that the factory had hardly got under way when the Armistice was signed, and the maximum output was never attained. Manufacture continued for a few months longer, but work ceased on 31 March, 1919.

The chief difficulty experienced at Basford was shortage of skilled labour, and the development period was prolonged owing to the lack of the skilled workmen required to supervise and train unskilled labour.

Wages were at first paid at plain time rates, but after a few months a special bonus for all operatives, amounting to about one-third of the standard time rate, was introduced, and this was continued until the the factory closed down. At the end of 1918 about 400 workpeople were employed, of whom 160 were women, the proportion of skilled labour to semi-skilled or unskilled in the machine shops being 1 to 3.

In October, 1918, after lengthy negotiations with the owner, arrangements were made to purchase the freehold for £14,500. Sums amounting to £3,500 were awarded to tenants for disturbance, and in December the capital expenditure on the factory was estimated at £46,500 for buildings and alterations, and £107,000 for machinery. The actual capital expenditure to 31 March, 1919, was £199,000.

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[1] C.G.M. 387Q ; C.G.2/97 ; M.I.D./R/2774 ; HIST. REC./R/1122/20 ; (Printed) *Weekly Report*, 1918, *passim*.

CHAPTER VIII.

NATIONAL FACTORIES FOR AIRCRAFT PRODUCTION.[1]

I. Introduction.

(*a*) *The Establishment of the Factories.*[2]

The sudden expansion of the aircraft programme in the summer of 1917 necessitated special steps for the production of aeronautical stores of all kinds. It was decided to reverse the policy of distributing the work among a large number of small producers and to concentrate in large units, for it was found that the tuition work involved in training the smaller firms was overtaking the supply of inspectors who undertook such duties as well as the actual testing of aircraft *matériel.* Moreover, questions of works organisation, assemblage space, finance and the allocation of material pointed to the superiority of the large unit, while experience in other branches of the Ministry tended in the same direction. The manufacture of the large bombing machines also necessitated large shops for assembly.

It was, therefore, decided to construct and equip several large aeroplane works at Government expense, to be operated under the control of the Department of Aircraft Production. Sanction was obtained in September, 1917, for the expenditure of £1,500,000 on three new factories for the production of aeroplanes, each with a capacity of 200 medium sized machines per month. Sites were selected at Croydon, Liverpool and Richmond, and arrangements were made for the management of the three new factories by Messrs. Holland, Hannen and Cubitt, Messrs. Cunard and Messrs. Sopwith respectively, on lines similar to those of the National Projectile Factories. The factory at Richmond was in reality a big assembly shop to be run by Messrs. Sopwith in conjunction with their other shops, and in the summer of 1918 it was decided that this should not be operated as a national factory, but should be rented from the Ministry by the Sopwith Aviation Company. A new factory at Heaton Chapel, belonging to Messrs. Crossley, the erection of which had been begun in the autumn of 1917, was selected for the third National Aeroplane Factory.

The limiting factor in engine production was the supply of skilled labour. Reorganisation of existing facilities appeared in 1917 to be the only way to increase production. In October, 1917, an aero-engine factory at Hayes, established at Government expense in the previous

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[1] For the general policy of the Ministry in regard to the State manufacture of aircraft, *see* Vol. XII, Part I.

[2] A.S.0924/1918; A.S.914/3/1918; A.S.924/2/1918; A.S.02842/1918.

January, was taken over as a National Aero-engine Factory under Government control, since its output was not satisfactory, and the automobile works of Messrs. Clement Talbot, Ltd., at Ladbroke Grove were acquired on 1 January, 1918, for the repair of Rolls Royce aero-engines. The works of the Motor Radiator Manufacturing Company, at Greet and Sudbury, were taken over in January, 1918, under the Defence of the Realm Act. The requirement of balloons also increased very rapidly at the end of 1917, and the premises of Bohemia Ltd., a cinema firm at Finchley were acquired for a National Balloon Factory. The original programme for national factories included several other establishments, but they afterwards lapsed into the status of extensions of existing private contractors' works.[1] Factories which were established at Oldham for assembling American machines were under the control of the Alliance Aeroplane Company until December, 1918, when they were nationalised with a view to reorganising the methods of management.

Special arrangements were also necessary for increasing supplies of British ash timber, and kiln drying facilities were found to be a limiting factor. Private kilns had been established in various parts of the country, and to supplement this capacity two drying kilns were built at Swindon and Lancing to be run as national concerns.

In the case of Liverpool, Croydon and Heaton Chapel, sites had to be found and new premises erected at a time when all classes of building labour and material were difficult to obtain. The difficulties met with in regard to building materials and labour accounted to a large extent for delays which were experienced in getting these factories into operation. Certain alterations and extensions were needed at Finchley and Greet, but at Hayes and Sudbury no construction work was necessary. The output at Hayes, Greet and Sudbury after they became national factories, increased in a most satisfactory manner.

(*b*) *Methods of Administration.*[2]

A special Factories Branch under the Supply Department of Aircraft Production was instituted in March, 1918; but it was decided in July, 1918, to divide the headquarters control and vest the responsibility for allocating work to the national factories and for the supply of materials, both to the trade and national factories, in the Controller of the Supply Department, while the administrative duties connected with output, efficiency, finance, labour, etc., in the National Aircraft Factories were placed under the control of a new department, to be known as the National Aircraft Factories Department. The Controller of the Supply Department dealt with each National Factory practically in the same way as with an ordinary contractor by means of production officers, but referred in all matters of management to

[1] These were the works of the Birmingham Carriage Company at Smethwick, the Metropolitan Carriage Company at Birmingham, and Messrs. Clayton and Shuttleworth at Lincoln.

[2] N.A.F./41/11/2, 11/7/2, 11/5/1, 15/6/1.

the Controller of National Aircraft Factories, who was responsible for the management of the factories, and was the official channel of communication with the Ministry regarding all matters other than those specially delegated to the Supply, Inspection and Technical Departments. The Controller had direct authority to sanction capital expenditure not exceeding £1,000 in any one case. Schemes involving larger expenditure were submitted to the Munitions Works Board.

The form of agreement with the managers of the National Aircraft Factories varied. The agency agreements at Croydon, Liverpool and Heaton Chapel followed, however, the same general lines. The managers were to superintend the equipment and completion of the factory as soon as possible, to begin the manufacture of aeroplanes and parts as soon as sufficient plant was erected, and to run the factory for continuous production. They were to engage and maintain an adequate staff, employing women wherever possible, and to manufacture from material supplied by the Ministry, with permission to purchase their own material up to £200 in cases of extreme urgency only. They were to receive in remuneration every six months 1 per cent. of the value of plant installed during the first year, 1 per cent. of the value of the total output of the preceding six months, with a minimum sum payable of £5,000, and $1\frac{1}{2}$ per cent. of the value of the interrupter gears produced in the same time calculated at £20 per gear. If the payment made to the managers caused such addition to the profits of their own business that they became liable to pay Excess Profits Duty, the Ministry undertook to pay the duty on the first £15,000 received by them in respect of aeroplanes and spare parts, and on the first £3,000 in respect of interrupter gears. The agreement might be terminated by either side on two months' notice. The fact that these agreements were not completed until several months after work was actually begun led to some confusion as to management in the early days.

The timber-drying kilns were managed by railway companies in whose works the kilns were erected, and the factories at Hayes and Finchley were managed by the Department of Aircraft Production directly. At Greet and Sudbury the existing management remained in control, and at Messrs. Clement Talbot's works the arrangements were peculiar, in that Messrs. Rolls Royce directed the works from a technical point of view. At each of the national factories the Ministry of Munitions was represented by a chief accountant. At first they were responsible to the factory managements, and in some cases, where they were formerly in the employment of the managing firms, their remuneration as factory officials was supplemented out of the funds of these firms. Under the Controller of National Aircraft Factories the position of the chief accountants was modified, and they became directly responsible to the Controller, their salaries being paid direct from headquarters.

The need for an increased output of aeroplanes was so urgent at the end of 1917 that special schemes were devised with the purpose of hastening the construction of the new aeroplane factories. The principal stipulation made was that a factory of stated capacity should

be erected and equipped within a stated time. The managing firms were to superintend the construction and equipment, and were paid part of their remuneration by a percentage on the cost of new buildings and plant. No detailed specification of the buildings were in existence when the expenditure was sanctioned, but the need for increased output made it difficult to wait for more economical methods. About 97 per cent. of the expenditure on factory construction had been incurred when the National Aircraft Factories Department came into existence, but from that time no new expenditure was sanctioned until detailed estimates were submitted and the fullest investigation made as to the necessity for the work.

The total cost of the State factories for aircraft production had amounted to £2,462,800 by the end of March, 1919. Of this sum by far the largest proportion, viz. £2,015,700, was the cost of the three factories for manufacturing complete machines at Aintree, Heaton Chapel and Croydon.

(c) *Accounts and Costing Systems.*[1]

Instructions as to the supply of materials to National Aircraft Factories were issued by the Supply Department in March, 1918. It was then laid down that except in special or urgent cases sanction should be obtained from the Ministry for all orders for material exceeding £200 in value. This regulation was by no means strictly kept, and some of the factories placed direct purchase orders for large amounts without reference to headquarters and accumulated stocks to an unjustifiable extent. The necessity for a more detailed system of control became apparent and such a system was instituted in October, 1918. By this the Ministry was protected against the risk of financial loss due to over-ordering, or irregular payments, and against the inequitable distribution of material and competition between buyers for various factories or the placing of large orders by the managing firms with their own shops. Delay in supply was not infrequent, and was often unavoidable owing to shortage of certain kinds of material. On the other hand, the factory managements did not always appreciate the necessity of anticipating their requirements.

In the agreements made with the various managers of the national factories it was laid down that efficient costing systems were to be set up. The method was, however, left to the discretion of the managers. The manager of Hayes Factory reported in January, 1918, that, owing to the unsatisfactory conditions obtaining at the factory in the past, it had been impossible to obtain even approximate figures of costs, but he hoped under a system which he had instituted to be able to give accurate results in the future. He suggested that a definite system should be laid down for all the national factories, but it was not until October, 1918, that a detailed system of costing was instituted for the purpose of determining the actual cost of manufacturing each unit, component and part. The difficulty of obtaining prices for stores in and out of the factories made cost accounts very difficult, and at

[1] N.A.F./41/11/2, 31/7/1, 11/8/2; A.S.17290/1918, 37532/1918, 14440/1918.

Aintree the confused state of stores accounts made it impossible to obtain costs. The expense of the system was considered to be no longer justified after the Armistice, and it was discontinued. When the system was inaugurated in October, the question was raised as to whether factory costs could be fairly compared with manufacturers' costs. The amount of depreciation to be written off the various assets was fixed by the Director of Factory Audits and Costs, and the rates were high compared with commercial standards, so that the overhead charges of the factory were unduly inflated. Comparison was also hampered by diversity of circumstances, as, for instance, at Hayes, where the relative smallness of the amount of work allocated made it impossible to work on economic lines, as it was necessary to cover the initial cost of jigs and tools on the price of a very small number of parts. In the case of balloon manufacture it was impossible to obtain costs for each operation, and for the purpose of costing, the manufacture was divided into three or four sections, each representing several operations. For the purpose of aeroplane costing the operations were divided as follows: (1) assembly of complete aeroplanes, (2) assembly of units, *e.g.* main planes, fusilage, (3) assembly of components forming each unit, (4) manufacture of parts required for each component.

The accounting work in connection with the National Aircraft Factories up to 30 September, 1918, was of exceptional difficulty, mainly owing to the non-observance of Ministry procedure by the factory managers and superintendents, and to difficulty experienced in obtaining the prices of stores, materials, machinery, etc., supplied through other departments of the Ministry. The managing firms who controlled agency factories were at first almost entirely unacquainted with rules and regulations governing expenditure on behalf of a Department of State.

The records, both of capital expenditure and of production payments, were very incomplete owing to the number of Headquarters Departments involved. In many cases where the prices of goods supplied had not been fixed at the end of 1918, these unpriced materials were regarded for accounting purposes as free issues, so that it became impossible to show the actual production expenditure, or the cost of the aircraft produced at the national factories.

(*d*) *Labour in National Aircraft Factories.*

Labour unrest was a constant source of difficulty in connection with the administration of the National Aircraft Factories. This applies particularly to Croydon and Aintree, and in a minor degree to Heaton Chapel and Kensington (Clement Talbot). On the other hand, labour disputes were of rare occurrence at Hayes, Greet and Sudbury, partly, probably, because the Ministry took over the employees of the former owners of these factories. The unsatisfactory nature of the output from the new National Aeroplane Factories was largely attributable to the labour conditions obtaining in these factories.

A production bonus was in operation for the workpeople at Heaton Chapel and Aintree. At Croydon one was sanctioned on 4 October, 1918, for the interrupter gear operatives, and at the Armistice one was

about to be authorized for the aeroplane workers. At Hayes, piecework was impracticable owing to the varied nature of the work, which consisted in the production of aero engine spares of numerous types, and in experimental work. The introduction of the ordinary production bonus was in contemplation at the time of the Armistice,[1] but some consideration in the form of a bonus on the value of the output was paid for some time before. It was also intended to allow a production bonus at the works of Clement Talbot, into which the shop bonus previously in operation was to have been merged, but this was abandoned at the Armistice. With the consent of the Labour Supply Department, the foremen were allowed an output bonus, with good effect upon production.

In the autumn of 1918, the employees in the National Aircraft Factories, exclusive of the Timber Drying Kilns, numbered 12,500, of whom 38·4 per cent. were women.

II. Individual Aircraft Factories.

The Aintree National Aircraft Factory, Liverpool (N.A.F.3).[2]

When plans were made in the summer of 1917, for the increased production of aeroplanes, the Cunard Steamship Company undertook to manage a factory at Aintree, Liverpool. The proposal was laid before the company in September, 1917, and an agreement was finally drawn up similar to that signed by Messrs. Cubitt, for the Croydon factory,[3] but at Liverpool, provision was made only for the manufacture of aeroplanes and spare parts, and not for interrupter gears. An annual payment of £1,000 was made to the firm in respect of supervision and was deducted from the 1 per cent. commission on output. The agreement with the firm was determined in September, 1918, on account of the small output reached, and the factory was directly controlled by the Ministry from the following November.

Rather more than 70 acres of land was acquired, under the Defence of the Realm Act, next to the Aintree race-course, which was used as a flying ground. Construction was begun on 4 October, 1917, but progress fell considerably behind expectations owing to the difficulties which arose in providing an adequate water supply and in laying connections with the Lancashire and Yorkshire Railway, while constructional work generally was much impeded by severe weather. Delay was also occasioned by the lack of a suitable type of labour. There appeared to be little difficulty in finding sufficient numbers, mostly Irish, but it was of very poor value. Early in 1918, over 3,000 labourers were employed on construction, but were reported to be "deplorable in spirit and quality," and ready to cease work for most trivial reasons. In March, many of the Irishmen left the country owing to the new Registration Act, and a labour officer was appointed

[1] N.A.F. 82/17/6.
[2] A.S. 913/1918; A.S. 0924/1918; M.C. 238; A.S. 0833/1918; N.A.F. 41/11/2.
[3] *See* above p. 199.

to deal with all questions of male labour. It was considered, later, that the large degree of autonomy accorded to the management had led to extravagance in the equipment of this factory, and that at Heaton Chapel. Building was complete in mid-July, 1917; but the layout was disappointing as it did not tend to efficient work or easy supervision.[1]

Although the office staff was established in March, 1918, production could not begin for several weeks, while the first finished machine was not despatched until 15 June, 1918. The managers undertook to construct 40 aeroplanes of the "Bristol Fighter" type per week, but the rate of production was at first extremely disappointing, 36 machines only having been delivered before 1 October, 1918, and, of those, 12 without engines. Manufacture, however, continued after the Armistice, and the total output of machines by the end of March, 1919, was 126.

Dilution was carried out to a considerable extent, and in September, 1918, of 2,634 employees, 1,054 (40·5 per cent.) were women. Labour difficulties, at first a serious problem, became acute in November, 1918, after the reorganisation of the management.

The capital expenditure to March, 1919, was £692,900.

Heaton Chapel National Aircraft Factory, Manchester (N.A.F.2).[2]

The National Aircraft Factory at Manchester was initiated as a trade factory in the autumn of 1917, in accordance with the scheme for the increased production of aircraft evolved during the summer. Sanction was given to the project in September of that year. The management was subsequently undertaken by Crossley Motors, Ltd., along the lines of the agreement common to the three National Aircraft Factories,[3] with certain modifications. It was agreed that should production be achieved under schedule prices, the firm should receive 15 per cent. on the reduction of costs effected. Messrs. Crossley superintended the erection of the factory, for which a separate building contract was made with Messrs. Matthews & Sons, and were responsible for the cost, receiving a commission of 1 per cent. on the sums payable to the builders during the first year. A standing contract with the firm for 500 machines was superseded by the new agreement, and a guarantee was given that the full output of 40 machines weekly should be reached by 1 July, 1918. In June, 1918, a separate agreement was drawn up by which the Government was to purchase the fee simple of the land from the firm for £15,000, and to reimburse to Messrs. Crossley the cost of construction, amounting to approximately £400,000. The firm was also granted the option of purchasing the factory within 12 months of the cessation of hostilities at 45 per cent. of the original cost.

The site selected was about 22 acres in extent, and ample space for a flying ground was attached to the factory. Construction began on 9 October, 1917, but was delayed by the need for extensive excavation.

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[1] Aircraft Supply Committee, Report on National Factories, 13.7.18.

[2] A.S.913/1918, 0924/1918; HIST. REC./H/1960/2; A.S 923/1918; N.A.F. 10/5/1, 31/7/1;

[3] *See* above p. 199.

Many difficulties arose during the course of erection, and the two aircraft factories being erected directly by the Ministry were granted a higher priority in obtaining labour and supplies than the Heaton Chapel factory which this firm was erecting. In spite of the many efforts made by Messrs. Matthews, the builders, to overcome this difficulty, all kinds of supplies were constantly delayed. In December, 1917, the firm was granted first-class priority for most of the material required and better progress was made. In July, 1918, extensions were arranged for the manufacture of Dragonfly engines.

Messrs. Crossley undertook the construction of D.H. 9 and D.H. 10 aeroplanes, but they were unable to reach the estimated output of 40 machines weekly. Manufacture began in April, and by the end of the summer the factory was making good progress. In October, machines were delayed owing to difficulty in obtaining engines, but the total output from Heaton Chapel before 31 March, 1919, was 326 aeroplanes, a figure considerably in excess of that shown by either of the other two National Aircraft Factories.

The labour difficulties were similar to those at Liverpool, although the numbers employed were not quite so great. No difficulty was anticipated in obtaining female labour, but dilution was not carried out quite so extensively as in other factories. Out of 2,540 employees in September, 1918, only 940 (37·5 per cent.) were women.

The approximate production expenditure to the end of March, 1919, amounted to £1,198,512, but the comparatively high output at Heaton Chapel was obtained from plant and buildings erected at a relatively low cost, the capital expenditure to March, 1919, being little more than £544,500.

Waddon National Aircraft Factory, Croydon (N.A.F.1).[1]

After the consideration and rejection of a site at Watford, Messrs. Holland, Hannen & Cubitt undertook, towards the end of September, 1917, to manage a factory at Waddon, near Croydon, and the proposed site was taken over under the Defence of the Realm Regulations. It consisted of about 198 acres of flat land at a fairly high level, which gave an ample flying ground and had reasonable travelling facilities, there being three stations within a distance of one mile. Construction began during the last week of September, and a member of the managing firm visited the Handley Page aircraft factory to investigate methods of production. Work was pushed on with all speed, and night-shifts were at work in November, but early in the new year progress was much impeded by a shortage of steelwork and by very bad weather, while the general inexperience of all concerned as to aircraft production caused the rate, both of construction and later of production, to fall short of the programme. By 18 January, 1918, the office staff was installed, and by the middle of March part of the factory was sufficiently equipped for manufacture to begin. All building work was practically finished by 13 July, 1918.

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[1] A.S. 913/1918, 0924/1918, 0789/1918, 23276/1917; 37715/1917; N.A.F. 24/4/3, 4; HIST. REC./H/1960/2.

The factory was laid out to produce 40 D.H. 9 machines plus spare parts, and 600 C.C. interrupter gears weekly. The first complete machine was delivered by the first week of April, and the total production by 31 March, 1919, was 241 aeroplanes and 3,000[1] C.C. gears. The factory never reached its estimated rate of production. The average output weekly, from August to October, 1918, was eight or nine machines only. In September, the output of C.C. gears was 50 per week. The unsatisfactory output was attributed largely to labour conditions among the electrical and woodworking trades and also to unsatisfactory management.

Labour conditions were particularly difficult at Waddon, where perpetual unrest was felt and the position was never satisfactory. About 2,000 labourers were employed on construction during the winter. In April, 1918, after manufacture started, 1,900 workers were employed, of whom about 50 per cent. were women, but it was estimated that in May, when the factory was complete, the number would have to be raised to from 5,000, to 7,000, 35 per cent. of whom would be on night shift. It was originally intended that 70 per cent. of the staff should be women; but at the beginning of November there were 200 women and 168 men on the staff and 1,791 men and 1,438 women working on the machines, so that of the total number (3,597) only 45·5 per cent. were women. Perpetual disputes occurred between the labourers and management; in May a strike of electricians resulted in some wilful damage to the electric supply plant, and in August the estimated output could have been reached but for labour disputes on the subject of wages, which were holding up the output of C.C. gears.

Nearly all the expenditure (97 per cent.) was incurred before the establishment of the National Aircraft Factories Department, which instituted a rather closer control over finance than had formerly existed. Considerable difficulty was experienced in estimating the exact expenditure involved in establishing the factory, since in order to hasten erection and begin work construction was begun on the " time and line " basis before detailed drawings and specifications were available. In August, 1917, when the site at Watford was considered, the estimated capital expenditure was roughly £290,350. The actual capital expenditure to March, 1919, was £778,300.

III. Individual Aero-Engine Factories.

National Aero-Engine Factory, Ladbroke Grove (Messrs. Clement Talbot, Ltd.).[2]

Very heavy demands for Rolls Royce engines were received by the Controller of Aeronautical Supplies in August, 1917, and special steps became necessary to hasten their production. The works of Messrs.

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[1] *See* HIST. REC./H/1960/2. Part I, Chap. XIX. Appendix.

[2] A.S. 8523/1917, 23290/1917, 36441/1917, 2403/1918, 12316/1918, 17841/1918; N.A.F. 93/15/7, 94/4/1; HIST. REC./H/1960/2; Minutes and Reports of Aircraft Supply Committee.

Clement Talbot at Ladbroke Grove were selected by the department as suitable for the purpose of repairing and producing spares for Rolls Royce engines. The firm was at that time chiefly employed on mechanical transport work, but they had suitable premises and plant for aero-engine work and had done some repairs to French aero-engines for naval service. Considerable delay occurred in starting on repair work. The provision of drawings from Messrs. Rolls Royce took three months, and as that firm was unable to provide jigs and tools, further delay occurred while Messrs. Clement Talbot manufactured those necessary. Great difficulty was experienced in cancelling the car contracts until the whole of the shops could be occupied in the manufacture of aero-engine parts.

Moreover, the change was scarcely to the interest of the managing firm, who had for many years been established makers of motor-cars and were suddenly called upon to undertake for a rival firm repairs of an aero-engine, with which they were unfamiliar. They feared that the scheme would involve them in post-war losses of money and prestige, and were accordingly unfavourably disposed towards it.

By the end of December little progress had been made, and since the requirements of the service for Rolls Royce engines were greatly increased at this time, some immediate steps became necessary. A conference was held between representatives of the Department, Messrs. Clement Talbot and Messrs. Rolls Royce, and it was agreed that the mechanical transport work should be cleared as soon as possible, and that the only work of this sort to be done by the firm in the future should be spares for the Talbot cars and ambulances, then running for the British Army, the rest of the capacity of the shop being turned over to the repair and manufacture of spare parts for Rolls Royce aero-engines. Messrs. Rolls Royce were to be responsible for the output and technical correctness of the work done in the Clement Talbot shops, sending technical experts to instruct the works manager there, but the latter was responsible for the general control of the works. All orders for repairs were given to Messrs. Rolls Royce, who allocated to Messrs. Clement Talbot as they thought fit, and were responsible for the proper supply of raw material. Messrs. Rolls Royce received a management fee for supervision.

The works were taken over by the Ministry on 1 January, 1918, at an annual rental and £202,996 was paid for the stock in trade. The agreement which took effect from 1 January, 1918, was to continue six months after the war, unless previously determined upon three months notice. At the termination of the agreement the company agreed to purchase all stock and work in progress. During the currency of the agreement the Minister paid to the company besides the annual rent and an annual sum for depreciation, a bonus of £5 per engine in respect of all engines repaired per week in excess of 15 up to 30 and £10 per engine in respect of all engines repaired per week in excess of 30. Arrangements were also made for the payment of a bonus on economical working according to a scheme to be prepared at the end of 1918 and to be applied retrospectively. The Ministry also paid all labour costs and overhead charges, excluding Directors' fees and salaries of the

managing staff, which were deemed to be covered by the amount of the rent and other remuneration.

Friction between Messrs. Rolls Royce's representatives and Messrs. Clement Talbot's managing staff still continued during 1918, and there was also much dissatisfaction among the foremen, because they understood that Rolls Royce employees were receiving higher rates of pay.[1] The question was raised in July as to whether these works should be taken from under the control of the Rolls Royce scheme, and in May a modification had been made as to the allocation of engines for repair between the two firms. From May the service section dealing with engines undertook direct allocation, on a basis of 60 per cent. to Messrs. Rolls Royce and 40 per cent. to Messrs. Clement Talbot, engines from the districts nearest Derby being sent to the former, and from the district near London to the latter. In August some changes were made in the managing staff at Messrs. Clement Talbot and a nominee of the Department of Aircraft Production was appointed as superintendent. Considerable improvement followed this reorganisation, and the agreement held good until the Armistice. The premises reverted to Messrs. Clement Talbot on 28 February, 1919. The total output of repaired aero-engines during the period while the works were run as a national factory was 608, the value being approximately £723,520, and it was hoped in October, 1918, that the output would eventually rise to 240 engines per month. Of a total of 1994 employees on 11 November, 1918, 371 (18·6 per cent.) were women. The capital expenditure to March, 1919, was £141,700.

National Aero-Engine Factory, Hayes.[2]

Arrangements were made in January, 1917, between the War Department and Messrs. Mitchell, Shaw and Co., Ltd., under which Mr. Mitchell should purchase the Goss Printing Works, at Hayes, Middlesex, over which he had secured an option of purchase at £95,000, in order to undertake a large contract for the supply of aero-engine parts then urgently required. Messrs. Mitchell, Shaw and Company as the Staines Projectile Factory, had been reported as having done very satisfactory work for the Ministry of Munitions. The War Department authorized the purchase of property and the provision of plant within a total sum of £135,000 out of money provided by the Government. The firm were to act as managers, receiving no working salary, but taking over the factory at the end of the war at a nominal sum of £100 if they succeeded in producing at half the ruling prices, which on the estimated output would save large sums to the Government. Mr. Mitchell accordingly entered into an agreement with the Goss Company on 26 January, 1917, to purchase the works for £95,000 plus £3,250 for work in progress. In February he entered into a contract for extensions amounting to £5,700.

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[1] Aircraft Supply Committee: Report on National Factories, 13.7.18.

[2] A.S. 4806/1918, 9597/1918, 8746/1918; N.A.F. 82/17/15, 83/15/3, 84/4/1; HIST. REC./R/400/12.

The Ministry of Munitions decided in October, 1917, to take over the management of the factory, as the output was not satisfactory. Mr. Mitchell acknowledged that the factory and plant were the absolute property of the Government and cancelled the arrangement under which the property should become his for a nominal sum.

After the change in management the organisation of the factory was much improved, and production increased. The factory eventually reached a particularly high standard in quality and quantity of output, efficiency of control and administration and freedom from labour difficulties. The wages obtaining there were in excess of the London district rates, and this caused some dissatisfaction in neighbouring factories, but no attempt could be made to adjust this without changing the rates which had already been established when the works became a national factory in October, 1917. Skilled labour was very essential in this factory for in June, 1918, it had been organised specially to deal with urgent requirements. The consequent constant changes in employment prevented the production of the factory reaching as high a figure as would have been the case had it been employed on repetition work. The nature of the employment in this factory to some extent precluded dilution, but in August, 1918, the dilution percentage was 38 and the management were working with a view to increasing this to 60 per cent. by the employment of discharged soldiers and women. The number of employees in October, 1918, was 761, of whom 213 (28·5 per cent.) were women.

Some extensions were made after the factory was taken over by the Ministry, the total cost being about £193,000, of which about £48,000 was written off to production as depreciation. The explanation of this was that the factory was originally intended for the manufacture of printing machinery, and the option price of £95,000 covered plant, stock and goodwill for that purpose. The balance sheet of the factory as an aero-engine factory was opened with the value stated as £52,000. The total capital expenditure to 2 April, 1919, was £211,346. The value of the output, which can only be assessed in this form owing to the variety of the work, was £348,992 from January, 1917, to 31 March, 1919. The factory was sold in September, 1919, to the Cosmos Consolidated Company for £112,500.

IV. The National Balloon Factory, Finchley.[1]

In order to meet the large demands for kite balloons in connexion with the anti-submarine programme and home defence scheme at the end of 1917, it became necessary to establish a national balloon factory. It was decided to take over a picture palace at Finchley, the property of Bohemia, Ltd. On 21 January, 1918, the premises were taken over under the Defence of the Realm Act for £18,500. A sum of £8,105 was approved by the Munitions Works Board for plant and alterations, but subsequently this amount was increased

[1] N.A.F. 51/13/1, 51/11/3, 52/10/1 ; HIST. REC./H/1960/2.

to about £16,000 of which about £11,000 was for building and the rest for structural alterations and furniture.

It was at first suggested that the Sidney Davidson Balloon Company should take over the new factory as an extension of their works, but finally it was agreed that this company and the Davidson Aviation Company should manage the factory on behalf of the Department, in co-partnership. Considerable delay occurred in completing the agreement for management, and it was decided in July, 1918, that the factory should be operated directly under the Controller of National Aircraft Factories, and the two companies were notified that their services were no longer required. Their joint remuneration for the period during which they acted as managers was agreed at the rate of £2,500 per annum.

The factory was used for the production of Caquot and Nurse balloons, and output began in April, 1918. The output of balloons varied greatly from week to week owing to intermittent supplies of material, but in October an output of ten a week was aimed at, and in the week ending 28 September nine had been produced. The total number of balloons produced up to 31 March, 1919, was 118, and the cost per balloon was reduced very considerably, as the following figures show :—

	£	Number Completed.
Approximate cost per balloon (R type) under old management to 2 July, 1918	400	12
Approximate cost, 2 July to 27 August	324	18
,, ,, 27 August to 30 September ..	275	10

A scheme for a bonus on production was being worked out at the time of the Armistice.

Difficulties in regard to labour conditions were increased during the summer of 1915, by pledges already given to the workers before the Controller took the factory over. In September labour difficulties were increased by the majority of the workers joining the Amalgamated Union of Engine and Crane Men, Boiler Firemen and Wire-rope Workers. The union immediately applied for increases of pay to the employees. The female workers had received a recent advance of 5s. a week which involved an increase of aproximately 5 per cent. on costing, and the further advance required, for which no reason was given, would have involved an additional 5 per cent. on costing. The women, whose wages compared very favourably with the district rate, had been quite content until they were disturbed by the active members of the union,[1] and the further increase demanded was not sanctioned. A large proportion of the employees were women, and at the date of the Armistice of a total of 297 employed 270 (90·9 per cent.) were women.

The factory was closed on 8 February, 1919, and was sold about June, 1919, to the Kiwi Polish Company. The capital expenditure up to the end of March, 1919, had been £16,500.

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[1] N.A.F. 52/10/1 ; 52/17/4.

V. National Radiator Factories, Greet and Sudbury.[1]

The advent of large bombing machines in the summer of 1917, raised a serious problem in the supply of radiators. All the heavy bombers had water-cooled engines requiring radiators of special construction, and it was found in August, 1917, that the capacity for radiator production was only a quarter of the requirement. The conditions prevailing in the trade were peculiar, for the number of firms engaged in the manufacture of radiators was less than a dozen, and most of them were small scale businesses. The employees, whose work was at a premium from the beginning of the war, were in most cases members of the Sheet Metal Workers' Union, and from the outset they resisted dilution and opposed everything tending in the direction of quantity production, so that increased output under existing circumstances was impossible. The position was so serious that the Department of Aeronautical Supply was obliged to assume control of the supply of radiators, which had previously been obtained independently by the aeroplane manufacturers, from the radiator firms. Contracts were re-arranged in order to reduce the number of types manufactured by each firm, and the development of a radiator factory on the lines of a national factory was decided upon.

The factory of the Motor Radiator Manufacturing Company, Greet, near Birmingham, offered several advantages for this purpose. It was laid out for the production of tube honeycomb radiators on a fairly large scale and produced 40 to 50 radiators a week. The plant was entirely self-contained, having a tube-mill producing all the tube necessary for the output of radiators. The buildings were modern and well lighted, the site was good and there was ample land available for extensions. Moreover the management was efficient and progressive, and since the employees were not members of the Sheet Metal Workers Union, the factory had for years been free from labour troubles.

After ineffectual efforts to transfer the business, which belonged to a Norwegian, to an English firm, it was finally decided to take over the factory under the Defence of the Realm Act. This was done on 1 January, 1918, and an extension of plant and works to treble the output was arranged in March. The negotiations for the purchase of the factory were prolonged, and were not finally settled until August, when a sum of £30,000 was paid as part payment of interest in the concern, and for stock and work in progress on 31 December, 1917.

Meanwhile the factory was run as closely as possible on the lines of a national factory although the management kept accounts in the same way as a private company, and tendered as before against other concerns for radiator contracts. Before the factory was taken over certain members of the staff had been paid on a salary plus profits bonus basis, and the employees worked on a piecework and profit bonus system. In view of the freedom of this factory from labour troubles it

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[1] N.A.F. 101/7/2; A.S. 28590/1918, 3120/1918, 23932/1918, 26986/1918, 72286/1918; HIST. REC./H/1960/2.

seemed advisable to continue this arrangement as far as possible, but in a national factory a scheme based on profits was impossible. The scheme finally agreed to was based on the output of radiators, with various bonus units corresponding to the previous percentage profits units. Some questions were raised as to the high salaries being paid under this scheme to the managing staff, but it was contended that the peculiar conditions existing in the industry justified this, which was the only way to obtain the full benefit of the experience of the firm and the staff as a whole. Radiator production in June, 1918, was barely abreast of requirements, and there was no margin available, so that every strike of the Sheet Metal Workers Union held up the production of aeroplanes, and continuous output from Greet was of the first importance. The efficiency of the factory justified a high remuneration for the management, especially as in this case nothing was paid to a managing firm. In 9 months from October to June, 1918, the total output of radiators increased tenfold. The output of the factory when complete was estimated at about 600 radiators a week, and even before the extensions were completed 20 per cent. of the Air Board requirements were supplied from Greet. The following are figures of output.

	Number of Radiators.
January, 1918 (5 weeks)	255
February (4 weeks)	327
March (4 weeks)	478
April (4 weeks)	556
May (5 weeks)	627
June (4 weeks)	619

A great advantage was gained by allowing the factory to tender for contracts in competition with private firms, for the factory tenders, allowing for liberal profits, were 10 to 20 per cent. lower than others obtained from private concerns, and this was of great value in negotiating with firms and reducing the cost of radiator production. At Greet was the only plant in the Kingdom producing radiator tubes by the Draw Bench method, and it produced tube at 4s. 9d. per lb. for which contractors charged 11s. 6d.

The management recruited and trained its own employees and the following figures show the extent to which dilution was effected during the first five months of 1918.

1918.	Employees.			Wages percentage to output.
	Men.	Women.	Total.	
January	169	106	275	28
February ..	183	151	334	23·6
March	198	192	390	21·3
April	206	236	442	18·7
May	237	213	450	16·9

By the end of October the total numbers had risen to 624, of whom 285 (45·7 per cent.) were women.

The factory at Sudbury, Suffolk, was a branch of that at Greet and was taken over with it. Until April, 1918, no separate accounts were kept for the Sudbury branch, material was supplied from Greet, and work done at Sudbury was treated in the same manner as if it had been carried out at Greet. The manager was responsible to the manager at Greet. As from 1 May, 1918, a new system of accounting was adopted, and accounts were kept at Greet for recording the transactions of the Sudbury factory, so that at fixed intervals profits and loss accounts and balance sheets could be prepared. Otherwise the management at Sudbury remained unaltered. Difficulty in obtaining labour made the employment of the Sudbury factory up to its full capacity impossible. At one time under 30 people were employed, though there was capacity for 130 to 150, and at the end of October there were only 56, 29 of whom were women. In July, 1918, Sudbury was organised to deal with the salvage and repair of radiators received from the Expeditionary Force. Some small additions were required to facilitate this work. The factory kept account of the costs of repair and salvage and added 100 per cent. for overhead charges plus 10 per cent. for profit. Great economies were effected, and for the three months ending 30 September, 1918, the value of the recovered material was £10,000, against which the wages bill totalled £1,500.

The factories at Greet and Sudbury were of the greatest value for emergency work throughout 1918. As an example of this the following may be quoted. Early in February, 1918, when the S.E. 5, a new scout machine, was approaching completion, it was decided to equip it with an underslung radiator of new design. No difficulty was anticipated as this type of radiator had been successful in the D.H. 9 aeroplane and some 2,000 radiators were put into production; but the first air trials showed that the speed of the machine was seriously reduced when fitted with this radiator. A conference of the designer of the S.E. 5 with the works manager of the Radiator Factory resulted in the preparation of rough drawings of a new type of radiator, and by working continuously by these rough drawings a new and successful radiator was despatched to Farnborough for trial within 48 hours of its conception. In the following week 40 pairs of this radiator were delivered from the factory, the next week 60, the next week 80, and the following weeks 100, so that the anticipated stoppage in the production of machines was entirely avoided. In the last weeks of March, when the Germans made their great effort, over 100 S.E. 5 radiators were shot through, and in order to replace them a special staff of courier air mechanics was provided. As each new radiator was completed at Greet an air mechanic set off with it and personally delivered it to its required destination in France.

The total output from both factories from 1 January, 1918, to 31 March, 1919, was 6297 radiators.

The capital expenditure on the two factories (Greet and Sudbury) up to March, 1919, was £64,600.

VI. National Timber Drying Kilns, Swindon and Lancing.[1]

The demand for aeroplane timber in September, 1917, necessitated the provision of facilities for kiln-drying British ash timber. In the autumn of 1917 a large number of kilns were put up by private firms, and it was arranged that some should be erected at the works of various railways. The Great Western Railway Company was at that time considering the erection of a kiln at Swindon for the post-war requirements of the company. Swindon was a peculiarly suitable site for serving the needs of the south-western district, owing to its railway facilities and to the fact that the company had an adequate sawing plant there, and negotiations were commenced by the Ministry with a view to securing the use of this kiln during the war. The first proposal was that the Ministry should build the kiln, but, since it was to be taken over by the company after the war, they preferred to supervise the erection, and it was finally agreed that the company should build at cost plus 12½ per cent., and buy the whole at a fair valuation after the war.

The building of a second kiln at Lancing in the works of the London Brighton and South Coast Railway was carried out by the Ministry, the railway company agreeing to take over the buildings at a valuation after the war. In the case both of Lancing and Swindon the companies undertook to manage the works after completion, on the terms of the general Government agreement with railway companies, under which all war work was carried out at cost price plus 12½ per cent. for superintendence. In order to simplify finance, the headquarters administration of the kilns was placed under the Controller of National Aircraft Factories, instead of directly under the Controller of Supplies (Aircraft Production), as at first suggested. Both kilns were finished in June,1918, and started work in July.

The estimated cost of erection was £4,400 in the case of Swindon and £3,500 in the case of Lancing, but both these estimates were exceeded. At Swindon improvements were incorporated during construction with a view to the post-war utility of the kiln, and at Lancing the extra cost was accounted for by the smallness of the contract and the poor quality of labour obtainable in the district. The final cost of the Swindon kiln was £6,510, and of Lancing £6,500; the capacity at Swindon, a four-compartment kiln, was 4,000 cubic feet per month, and the approximate total output to 31 March, 1919, 9,800 cubic feet. The capacity at Lancing, a two-compartment kiln, was 2,000 cubic feet per month and the approximate output to 31 March, 1919, 5,000 cubic feet. At this date both kilns were handed over to the railway companies. The surplus capital expenditure for the Swindon kiln was sanctioned by the Munitions Works Board in November, 1918, but the outlay on the kiln at Lancing had been made under the authority of the Railway Executive Committee, and sanction by the Board was not considered necessary.

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[1] A.S. 36172/1917, 27372/1917; N.A.F. 64/4/1.

CHAPTER IX.

MISCELLANEOUS NATIONAL FACTORIES.

I. National Gauge and Tool Factories.[1]

Certain classes of factory equipment, namely gauges, small tools and ball-bearings were manufactured to some extent in state factories. The National Gauge Factories were in practically every case existing trade establishments which by agreement between the Ministry and the proprietary firms were reorganised and placed under the administrative and financial control of the Ministry. These agreements arose from the necessity of increasing the supplies of gauges, combined with the difficulties involved in spreading small contracts over a large number of firms which were themselves in difficulties as to labour and precision machinery. The urgent need for immediate supply and the problem of finding the necessary staff prevented the erection of one central state gauge factory, as was at times suggested, and consequently various successful makers were selected to whom aid was given to extend their existing works on behalf of the Government.

The first factories so organised were at Woolwich, Birmingham and Croydon, where in the summer and autumn of 1915 engineering firms agreed to extend or adapt their works for gauge production and to manage them under the direction of the Ministry. The financial arrangements made with the different firms varied considerably and were subsequently revised at intervals, but in each case the Ministry eventually became responsible for all or the greater part of the cost of extension and absorbed the whole of the finished output.

In 1917, the Wolseley Motor Company at Pimlico and in the spring of 1918, the Newall Engineering Company at Walthamstow undertook gauge manufacture for the Government. In these two cases the Ministry took over the entire management of the factories, although, with the exception of new buildings and plant erected during the war, they remained the property of the firm, who received a fixed sum annually as profit and in respect of depreciation of machinery. The cost of working and maintaining the factories was borne by the Ministry. In May, 1917, the Fairfax National Gauge Factory was established at Kilburn, and was regarded financially as an adjunct of the Wolseley factory. The Fairfax Factory was managed by Mr. W. T. Bassett Lowke, who was experienced in gauge work, and employed 15

[1] Vol. VIII, Part III, Chapters I and II; Hist. Rec./R/400/57. (Printed) *Weekly Report, passim.*

skilled enemy mechanics, who produced a satisfactory output. The output from all these factories except that at Birmingham, from which the main output was small tools, taps and dies, was sent to the National Physical Laboratory, Teddington, where the gauges were invoiced at cost, plus 10 per cent. profit. Most of the gauge factories involved a capital expenditure of slightly over £20,000 each. After the Armistice they either continued gauge manufacture, chiefly for aircraft work, or were turned over again to their normal work. The Fairfax factory was closed and the workers reinterned.

The supply of small tools fell considerably short of the requirements at the beginning of 1916, and though no general control of the small tool trade was instituted until later, various firms were induced to extend their works, and in one instance new plant was set up for the State manufacture of tools which were particularly difficult to supply. This was the new National Tool Factory at Gateshead. The Ministry also took over the direction of the Coats Machine Tool Company's works at Westminster, on the ground that the inferior quality and high cost of the output was due to mismanagement; it appointed a managing director, and became responsible for working expenditure. The Gateshead factory began production of spade-cutters in August, 1916, and reached its estimated output of 3,000 cutters a week by the end of the year, while subsequent extensions enabled this quantity to be increased to 5,000 per week. Dilution was extensively carried out, and the financial results attained were excellent. The Coats Machine Tool Company's factory produced tools of all kinds, and by 1917, after the reorganisation by the Ministry, its weekly output was valued at £800 to £1,000. In September, 1917, the works of the Hoffman Manufacturing Company at Chelmsford, which were producing ball-bearings on a large scale, became a national factory. The business was bought up by the Ministry as, in view of its post-war prospects, the firm was unwilling to extend the factory any further to meet the needs of the new aircraft programme, while difficulties as to future commercial competition prevented the firm's exceptional technical abilities being used for the benefit of other factories. The managers placed their services at the disposal of the Ministry. The estimated cost of purchase in March, 1918, was £1,500,000. Under the control of the Ball Bearings Branch, working in close connection with the Aircraft Supplies Department, the two managing directors continued to work the factory as agents for the Ministry. A high standard of efficiency was maintained throughout the war, the output being steadily increased from some 72,000 bearings monthly early in 1915, to 230,000 in October, 1918.

In the autumn of 1918[1] the total number of employees in all these factories, excluding Chelmsford, was about 1,600, of whom 25 per cent. were women. The capital expenditure on the factories, exclusive of Chelmsford, was £95,600 to 31 March, 1919.[2]

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[1] The figures taken for Birmingham, Kilburn and Walthamstow, are for March, 1918, the latest available.

[2] The figures for Pimlico are for March, 1918.

A list of the national gauge and tool factories is given below :—

Factory.	Administration.	Date of Establishment or Nationalisation.
National Gauge Factories—		
Woolwich	Messrs. Pitters Ventilating and Engineering Company.	1915
Croydon	Vidal Engineering Company ..	1915
Birmingham ..	Messrs. Chatwin	1915
Pimlico	Wolseley Motor Company ..	1917
Kilburn (Fairfax) ..	Direct Control	1917
Walthamstow ..	Newall Engineering Company ..	1918
National Tool Factories—		
Gateshead (spade-cutters).	Direct Control	1916
Westminster (small tools).	Coats Machine Tool Company ..	1917
Chelmsford (ball-bearings).	Hoffmann Manufacturing Company.	1917

II. National Factories for Salvage, Repair, and Rectification.[1]

The responsibility for the repair of *matériel* returned as salvage from the battle area was at first vested in several different departments of the Ministry. Thus, all material was first received and sorted by the salvage depôts, established at several towns on the coast by the Salvage Department. The actual work of repairing or re-manufacture was undertaken to a large degree by contractors as a subordinate part of their whole programme. A rapidly increasing amount was done by the National Box Factories,[2] controlled by the Timber Supply Department ; ammunition and boxes were repaired in the State factories at Dagenham Docks and Newport (Mon.), under the administrative control of the Small Arms and Small Arms Ammunition Department, and boxes for bombs and grenades were dealt with at Beddington National Box Repair Factory established by the Trench Warfare Department. Gun carriages were repaired at the National Gun Carriage Repair Factory, Southampton, under the control of the Gun Manufacture Department, and fuses were rectified in a factory in Gray's Inn Road, administered by the Shell Manufacture Department. At the end of 1917 a reorganisation of administration resulted in a closer co-operation of Salvage and Stores Departments under one controller.

[1] M.C., 62, 244, 456 ; HIST. REC./R/1122/20 ; Vol. XI., Part I, Chap. II, Appendix IV ; HIST. REC./R/400/57 ; D.G.I.M./General/402 ; C.G.M. 387 Q.

[2] *See* below p. 219.

The five depôts controlled by the Salvage Department were placed at Blyth, Immingham (near Grimsby), Trafford Park (near Manchester), Renfrew and Ridham. Little constructional work was required, as in most cases land was either taken over under the Defence of the Realm Act, or was lent to the Ministry by the owners for a specified time, and where existing accommodation could not be adapted to the new purpose, buildings of a temporary nature were rapidly erected. The depôts were occupied in receiving, storing and sorting Q.F. cartridge cases and boxes, heavy artillery ammunition components and anti-gas equipment, and in despatching them to various stores and factories in accordance with the allocations received from the Stores Departments concerned. In June, 1918, the number employed in four of the five factories[1] only totalled 1,268, and of these, some 75 per cent. were women. Unlike most of the national factories the salvage depôts were required to continue work after the cessation of hostilities with probably increased labour, as more shipping facilities, on which their work was entirely dependent, would then be available for transport from the various fronts. The capital expenditure on all five up to March, 1918, amounted to £59,100.

The National Cartridge and Box Repair Factories at Dagenham and Newport acted as receiving depôts for salved munitions, and also carried on the work of rectification on a large scale. The Dagenham factory was at work early in 1916, but at the end of the year extensions to the factory were made, and female labour introduced, so that by the spring of 1917 the combined programme of the two factories provided for the repair of 650,000 18-pdr. cartridge cases, 100,000 4·5-in. cartridge cases, and more than 175,000 ammunition boxes per week. Much difficulty was experienced in finding skilled workmen, and men were imported from Ireland or lent by individual firms to push forward the work. In April, 1918, of 3,772 workers at the two factories, 88 per cent. were women. The capital expenditure on the two factories was £438,300 in March, 1918.

Buildings at Beddington, near Croydon, were rented in November, 1916, by the Trench Warfare Supply Department and converted into a National Box Repair Factory for the repair of bomb and grenade boxes. Work was started early in 1917, and by September, 15,000 boxes were repaired each week, practically all the workers being women. In October, 1918, female labour represented 89 per cent. of the total number employed (318). The cost of repairing was halved by April, 1917, and the total expenditure on land, buildings and plant amounted to £7,200.

The National Gun Carriage Repair Factory at Southampton was transferred to the Gun Department at the beginning of 1918. The factory had been used for some time by the Carriage Inspection Department, Woolwich, as an inspection depôt for the sentencing of carriages returned from overseas, and had been extended at a cost of £6,500. Repair work started in the spring of 1918, and after a few months

[1] Renfrew was temporarily closed.

20 carriages a week were being turned out. The repair of breech mechanisms was also undertaken. There was no lack of labour at Southampton, and when the Ministry took over the factory, only 2 per cent. of the employees were women. This percentage was, however, raised to 30 by the end of October, 1918, when the total number of employees was 174. The capital expenditure to 31 March, 1919, amounted to £18,600.

Fuse rectification was carried out at the National Fuse Rectification Factory, Phœnix Place, Gray's Inn Road.[1] The premises were taken over under the Defence of the Realm Act, at the beginning of May, 1916, additional accommodation in an adjacent garage being taken later. Messrs. William Cubitt, who were already rectifying fuses in their works in Gray's Inn Road, undertook as agents of the Ministry, to alter, equip and manage this factory, for the conversion of American supplies of the No. 100 fuse to No. 102. An agreement was concluded in October, 1916, providing that all production costs should be paid by the Ministry and the firm should receive as a fee 10 per cent. of such costs. A sum of £10,150 was to be paid the firm for expenditure on equipment, etc., and a further sum of £3,300 was subsequently sanctioned for additional alterations. At the end of 1917, the factory changed over to the conversion and rectification of fuse No. 101 and the original agreement was modified, a fixed sum of 1d. a fuse being paid to the firm instead of a percentage. Other work done included the hardening of stocks of soft steel needles for fuses. The employees in October, 1918, numbered 522, of whom 70 per cent. were women. The capital expenditure to March, 1919, amounted to £22,500.

A list is given below of the national factories for salvage, repair and rectification, which with the exception of the Fuse Rectification Factory, were under the direct control of the Ministry.

Factory.	Purpose.
Government Salvage Depôts—	
Blyth	Receiving, sorting and dispatching salvage.
Immingham	
Renfrew	
Ridham	
Trafford Park (Overseas Salvage)	
National Cartridge and Box Repair Factories—	
Dagenham Dock	Receiving and repairing ammunition and boxes.
Alexandra Dock, Newport	
Beddington (Trench Warfare)	Repairing bomb and grenade boxes.
National Gun Carriage Repair Factory—	
Southampton	Repairing gun carriages.
National Fuse Rectification Factory—	
Phœnix Place, London	Conversion and rectification of Fuses No. 100 and No. 101.

[1] 15/Muns./2554, 94/F./1259.

III. National Box Factories and Sawmills.[1]

When the Ministry of Munitions became responsible for the supply of ammunition boxes, the patterns being made were still chiefly of the pre-war type, used for transport to the Colonies. New designs were then made for less expensive and elaborate types and contracts placed with various wood-working firms. Supply was arranged on the open tender system, which resulted in considerable disorganisation of plant and labour, by reason of the frequent changes made in the contracts placed with different firms. The Timber Supplies Department of the Ministry, therefore, established National Box Factories to avoid the difficulties involved in the contract system and to meet emergency demands for cases urgently needed. In addition to filling these requirements the National Box Factories, of which the first two were in operation by the end of 1916, also effected considerable economy by converting into the packages for which it was most suitable, timber returned by contractors as unsuitable for their particular work, and material obtained from boxes salvaged from abroad[2] or brought into the country as packages for overseas supplies. In many cases buildings were taken over in proximity to the filling factories and undertook the repair of transit cases used by the latter.

The London area was served by the first two factories at Deptford and Woolwich, and in January, 1917, a large factory at Willesden, near the Park Royal inspection works, was purchased from the Standard Woodwork Company. In April, 1917, work began at Erith and Willesden on non-returnable boxes from overseas, which were either repaired for re-use, or converted into caseboards for new boxes. This proved to be a most successful section of the work, and some 400 tons of timber was utilized each week. By October, 1917, ten National Box Factories were at work, and boxes were being broken down at the rate of 80,000 per week, yielding approximately 200 standards of usable timber. Although more skilled tin-workers were available in the North of England, tin or tin-lined packages were first repaired at Deptford to avoid the transport of salvage landed in the South to the North and back again, most of it being re-despatched from London. In 1918, additional factories were taken over for this work at Maidstone, Guildford, Luton, and Paisley. Delays occurred at the box-factories from time to time, owing to the congestion at the ports, and the time required to sort out salvaged components which were returned in the boxes, but the output generally was very satisfactory. During the spring, some of the factories were concentrated on cordite cases and boxes required by the Trench Warfare Department for various explosives, and on other urgent work. Extensive dilution was effected, the percentage of female labour to the whole number employed

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[1] HIST. REC./H/1860/5; HIST. REC./R/400/57, 1122/10, 20; S.M.I./466; D.D.G.E./E.M.5/68, 1; D.G.I.M./Gen./402.

[2] *See* under Salvage and Rectification Factories. (p. 217 above.)

being in many factories as high as 87 per cent. In October, 1918, of the total number (approximately 2,300) employed in 14 of the factories, 69 per cent. were women.[1] In nearly every case, except at Willesden, factories previously engaged in various kinds of woodwork were taken over by the Ministry as "going concerns," being rented for a period slightly longer than the duration of the war. The majority of the factories were directly controlled by the Timber Supplies Department of the Ministry, although where possible members of the existing staff were retained under the supervision of an official appointed by the Ministry, but in some cases the original owners continued to manage the works as agents for the Government. The capital expenditure on all the factories up to 31 March, 1919, amounted to approximately £66,000.

The caseboards for 18-pdr. and 4·5-in. shell boxes were imported, but to supply timber for urgent requirements and for miscellaneous packages, sawmills were taken over by the Ministry. In September, 1917, one national sawmill in England and three in Scotland were at work, and in October and November of that year, when the Timber Supply Department of the Board of Trade had instituted more extensive felling operations, additional mills were acquired at Luton, Southampton, Poole, Gloucester and Warrington as well as three more in Scotland. Early in 1918 a further factory was started up at Berwick-on-Tweed.

Practically all the original owners of the sawmills continued to work as Government agents; timber was supplied by the Ministry and an inspector was placed in each mill to ensure that the stocks received were properly accounted for and cut as required. The chief difficulty found in utilizing home-grown timber was the problem of drying the wood sufficiently in a short time. For this purpose drying kilns were erected, first in the Glasgow and London areas and later in connection with most of the larger sawmills, but many were not ready for use until the summer of 1918. The output of caseboards suitable for boxes was retarded in 1918 by the poor quality of the timber supplied to the mills, and by the great difficulty experienced in obtaining labour. At Luton Austrian prisoners were employed, while at many factories the lighter sawing was done by women. In the autumn of 1918, of 1,200 employees in the factories, 650 (53 per cent.) were women. The caseboards produced in the national sawmills were 8 to 10 per cent. less expensive than those purchased from overseas. After the Armistice, practically all the box-factories and sawmills with the exception of Willesden, reverted to their pre-war owners who turned over again to their normal production. The capital expenditure on the twelve mills at work in the summer of 1918, amounted to £30,481 by March, 1918, and to £81,300 a year later.

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[1] No figures are available for Luton and Maidstone. The figures taken for Guildford and the two Paisley factories are those for April, 1918, the latest available.

The following list shows the chief national box-factories and sawmills under the control of the Ministry :—

Factory.	Administration.	Date of Establishment or Nationalisation.
Box Manufacture and Repair—		
Castleford	Direct Control	1917
Leeds	Messrs. J. H. Abrahams	1917
Letchworth	Co-Partnership Company, Ltd.	1917
Liverpool	Direct Control	1917
Luton	Direct Control	1918
Paisley No. 1	Direct Control	1917
Willesden	Direct Control	1917
Woolwich	Messrs. W. Watt Torrance and Company.	1916
Tin Box Manufacture and Repair—		
Deptford No. 1	Direct Control	1916
Deptford No. 2		1917–18
Glasgow		1917
Guildford		1918
Luton		1918
Maidstone		1918
Paisley No. 2		1918
Non-Returnable Box Depôts—		
Erith	Direct Control	1917
Willesden		
Sawmills—		
Berwick	Messrs. Allan Brothers	1918
Dumfries	—	1917
Elgin	Messrs. A. Watson & Company	1917
Glasgow	A. McDougall's Timber Company.	1917
Glasgow	Messrs. J. Smellie & Company	1917
Gloucester	Messrs. Joseph Griggs & Company.	1917
Inverness	Messrs. J. Walker & Company	1917
Kilmarnock	Messrs. Brownlie & Company	1917
Luton	Messrs. Henry Brown & Sons	1917
Poole	Messrs. J. T. Sydenham & Company.	1917
Rotherhithe	Messrs. Priddy & Hale	1917
Southampton	Messrs. Driver & Company	1917
Warrington	Messrs. R. A. Naylor, Ltd.	1917

IV. Cowley Mine Sinker Assembly Station.[1]

Early in 1917, the Trench Warfare Supply Department undertook to meet an urgent Admiralty demand for mine sinkers. Owing to the difficulty of placing orders for complete sinkers, it was decided to

[1] HIST. REC./H/1600/6 ; HIST.-REC./R/400/57.

produce the bulk of the requirements on the group system and assemble the parts at a central station. At the end of March, a central assembling station was established at Cowley near Oxford, in the works of Messrs. W. R. M. Motors Ltd., a firm experienced in trench warfare work.

A large empty building, 240 ft. by 135 ft., was available, and part of the firm's main works were also used. By the agreement with the firm, rental based on the assessment value was to be paid for a period of three months from 25 March, 1917, and thereafter subject to one month's notice on either side. The work of assembly was to be carried out under the direct supervision of Mr. W. R. Morris, of the firm whose works were used. The services of the works manager and office staff were also to be available, and a proportion of their salaries to be paid by the Ministry. All outgoings, including wages, were to be borne by the Ministry.

Little structural alteration was necessary, but a considerable amount of equipment had to be supplied at government cost. At the end of August, some additional accommodation was found to be necessary for inspection purposes. Sidings were constructed on the Great Western Railway, communication with the assembly station being affected by means of a narrow-gauge railway.

Delivery of complete Mark VIII sinkers began at the end of August, 1917; an output of 750 a week was reached by October, and was maintained at that rate. At the beginning of 1918, a slightly different type, Mark VIII*, was undertaken, entailing some re-organisation.

In January, 1918, the employees at the assembly station numbered 411, 36 per cent. being women, but by the autumn the amount of work to be done had been reduced and numbers had fallen to 246, of whom 76 were women. The capital expenditure up to March, 1918, amounted to £21,600.

V. The National Machine Gun Factory, Burton-on-Trent.[1]

In the autumn of 1917, when a review of the requirements of machine guns for 1918 showed that the increasing output from existing factories would not be adequate to meet the greatly increased demands made by the extended programmes of air and tank warfare, the project of setting up a national factory for the production of machine guns was considered. The scheme, as suggested at a specially convened sub-committee of the Munitions Council in September, 1917, provided for the erection of a factory outside the day air-raid area with a producing capacity of 400 machine guns per week. The project received Treasury sanction on 25 October, 1917, and arrangements were at once made for carrying it into effect.

A site was chosen at Burton-on-Trent, where 153 acres were acquired for the factory from the Marquis of Anglesea by private treaty. The factory was planned for construction on the most rapid lines, being built of brick, steel framed, part plaster, part board with

[1] HIST. REC./R/1122/45; 1410/2, 13; M.C. 20; D.G.F./M.G.F./33; D.D.G.E./E.M. 8/475, 495.

slate roofs. The contract for construction was given to Messrs. Thomas Lowe & Sons. By March, 1918, building was progressing satisfactorily, and plant, tools and fixings had been ordered. When the Armistice was declared, the factory was still in course of construction, and the first output was not secured till the week ending January 4, 1919, when repaired machine guns began to be delivered.

The management of the factory was put in the hands of a superintendent, Colonel Mills, appointed by the Government, and a small staff. As labour was not required for working machines at this factory until after the Armistice the problem of securing sufficient workers did not arise. All labour difficulties at Burton were concerned with protests made by the local Trades Council in May, 1919, against the closing of the works.

In May, 1919, orders were given for the closing down of the factory as a working unit, and for its conversion into a store for guns and machinery. Accordingly in May and June arrangements were made for carrying out these orders, and the factory was closed down.

Before the decision to close Burton had been made final, the plan for the disposal of the works was a matter of considerable discussion. It was suggested that Burton should be kept as a working unit for production and repair of machine guns in order that a permanent centre of trained machine workers and running machines might be provided from which expansion would be possible in case of emergency. The experience of 1914, when the lack of skilled workers had been a severe check on production, made evident the need for some centre for training workers in machine-gun production if such delays were to be avoided in the future.

While this proposal received serious consideration it was decided that the expense which it involved would be too great to justify it. The shops at Woolwich and Enfield could be adapted to the manufacture of machine guns should need arise, and there was strong probability that a new design of gun would be evolved before any considerable demand would again be made, and therefore that the skilled labour and machinery producing one type of machine gun at Burton might fail to be of the advantage that was expected by the promoters of the scheme.

The probable cost of the factory had been estimated in September, 1917, as £750,000. By the end of 1919 the total actual capital outlay on construction, plant, etc., was estimated at £879,581, with the addition of £12,829, the cost of the site, bringing the total up to £892,410 for the complete undertaking.

VI. National Factories for Optical Munitions.[1]

The Kentish Town Factory.

Before the outbreak of war, very few firms in England were engaged in the manufacture of optical instruments, and to meet the demands of the services considerable extensions of existing plant had to be

[1] Vol. XI, Part III, Chap. II; O.M.G./Gen./2305, 3210.

carried out, but no national factory was established until the end of 1917. The demands were then greatly increased and the Periscopic Prism Company, on which the Ministry was largely dependent for supplies, found it impossible to cope with the proposed programme for 1918 unless extensive additions were made to its factory at Kentish Town. The company, therefore, applied to the Ministry for financial advances. The additional capacity was urgently needed to supply optical sights for aeroplane guns, telescopic sights for rifles, gun-sighting telescopes for the Admiralty, and other types of optical instruments. The organisation and experience of the management were most satisfactory and it was accordingly decided to take over the factory entirely, bringing both the original works and the new extensions under the control of the Ministry. The shares of the company were bought up, although the business was still retained in the form of a limited liability company, and thus from 28 February, 1918, the factory was brought under the control of the Controller of Optical Munitions, Glassware and Potash Production Department, three Directors being appointed to manage the works on behalf of the Ministry.

Plans were submitted for new buildings on adjoining land belonging to the factory, but considerable delay occurred in the construction until August, after which better progress was made and the output materially increased, instruments of various kinds being produced to the value of some £100,000. The cost of the extensions to the works carried out during the summer amounted to approximately £46,100 and the total cost of taking over the company involved some £80,000.

In May, 1918, the employees numbered 204, 43·6 per cent. being skilled men, and 31·8 per cent. women.

National Photographic Lens Factory, Brimsdown.

In 1918, further plant for photographic lenses was set up by the Ministry at Brimsdown near Enfield. The large quantities of lenses required for the Hythe Gun Camera evolved by the Air Force, had been for a considerable period produced in France. In 1918, owing to various manufacturing difficulties, including the scarcity of coal, production in France became impossible and as English lens manufacturers were already working to their full capacity the National Photographic Lens Factory was established. Mr. Emerson of the Guaranteed Lens Company, who had much experience in lens production, undertook to manage the factory for the Ministry, and the freehold of suitable premises at Brimsdown was purchased. After some delay, the factory was started up, the first lenses being delivered in July, 1918, and supplies continued to be delivered regularly until the Armistice.

The capital expenditure was estimated in July as approximately £3,000. The actual expenditure to 31 March, 1919, amounted to approximately £6,000.

VII. National Concrete and Steel Billet Breaking Factories.[1]

Early in 1918, owing to the difficulties experienced in the construction of new factories and depots, two national factories for concrete and plaster slab production were established by the Steel and Iron Department of the Ministry, to provide some of the materials required for large building operations.

At Gotham, in Nottinghamshire, land was leased by Messrs. King & Company for the erection of a new factory, the cost of building and equipment, which by 31 March, 1919, amounted to £16,600, being borne by the State, while the firm had the option of taking over the factory after the war at an agreed valuation.

At Yate, near Bristol, a factory was erected and managed by Messrs. Robert McAlpine & Sons, as agents for the Ministry. An official of the firm was appointed as manager, and as he devoted a part of his time to administrative work at the neighbouring Western Aircraft Repair Depot, which was also controlled by the firm, the administration and financial control of the factory and depot were not at first entirely distinct. The factory produced huts, walls, ferro-concrete fence posts, or poles for carrying electric cables, chiefly for use in the erection of new national establishments, and production had begun by June, 1918, although some construction was still in progress, and some difficulty had arisen in connection with railway facilities. The number of employees at this date was 125 men and 15 women. The original estimated capital expenditure was £20,000, but in June it seemed probable that this sum would be considerably exceeded. The actual sum expended by 31 March, 1919, was £39,700.

Two other national factories (as distinct from mines and quarries) were controlled by the Steel and Iron Department. The one was the Billet-breaking Factory, at Trafford Park, Manchester. This was established at the end of 1916, to deal with the steel billets, then shipped from America. The specification for shell steel required that all billets or bars should be broken to shell lengths to ensure soundness on inspection, and as sufficient capacity was not available at contractors' works to cope with the imported billets, plant was set up for the purpose at Manchester and the National Projectile Factory, Lancaster. The Trafford Park Factory, at Manchester, was erected next to the Ship Canal, by which the steel was brought from Liverpool, and was directly controlled by the Ministry. It contained the largest billet breaking plant in the country and accounted for 7,000 of the 14,000 tons which represented the average weekly amount of steel imported from America, the remaining 7,000 being distributed between the Lancaster Factory and various contracting firms. Sufficient broken billets were despatched each week from Trafford Park to the forgemasters and national factories for the manufacture of 150,000 shells of all sizes between 18-pdr. and 9·2-in. The number of employees in October, 1918, was 529, and the percentage of women was 21·6. The capital expenditure on the factory to March, 1918, was £142,200.

[1] HIST. REC./H/1810/5; D.F.C./C/57; HIST. REC./R/1122/20, 45.

At Merthyr Tydfil, rolling mills were established at State expense in connection with the blasting furnaces of Messrs. Crawshay Brothers, which were also taken over by the Ministry, and worked under an agency agreement for the period of the war and six months after. The works were originally engaged in producing basic pig from native ores, and, during the war, rolled 18-pdr. H.E. shell-steel bars from American ingots. The total number employed in the blast furnaces, rolling-mill and engineering shops was 904, of which less than 1 per cent. were women. Up to 31 March, 1918, £26,500 had been expended on the blast-furnace, and £51,800 on the rolling-mills.

The following is a list of the national factories controlled by the Steel and Iron Department of the Ministry for various purposes :—

Factory.	Administration.	Purpose.
Gotham.. ..	Messrs. J. A. King & Company	Manufacture of plaster slabs.
Yate	Messrs. Robert McAlpine & Sons.	Manufacture of concrete slabs.
Trafford Park (Manchester)	Direct Control	Steel billet-breaking.
Merthyr Tydfil..	Messrs. Crawshay Brothers, Ltd.	Rolling mills and blast furnaces.

VIII. National Chemical and Anti-Gas Factories.[1]

National Factories for Chemical Manufacture.

In the spring of 1915, the first demands for chemical supplies were met by extensions to the works of existing manufacturers, and, with the exception of the Admiralty Factory at Stratford, which was occupied largely upon experimental work, no Government factories were established for chemical manufacture until April, 1918, since the experience and practical knowledge of chemical firms were essential to the successful development of new plant. In April, 1918, responsibility for chemical warfare supplies was transferred to the Explosives Supply Department, partly to facilitate the use of spare capacity in National Explosives Factories for poison gas production. The policy of this department was to produce the large quantities of arsenic compounds and mustard gas then required in state factories, since existing trade capacity was by that date fully absorbed. The greater part of the capital outlay upon national plant for the production of lethal substances was incurred in the conversion and installation of plant for the manufacture of mustard-gas and arsenic compounds during the year 1918. It was estimated that the cost of the scheme for producing these two classes of chemical would involve an outlay of £394,500 upon national factories.[2] Of the factories previously engaged on the manufacture of explosives, H.M. Factories at Sutton Oak and

[1] *See* also Vol. XI, Part II, Chap. III and IV.
[2] X/CW/709.

Ellesmere Port,[1] formerly manufacturing synthetic phenol, were converted at a cost of some £59,500, for the production of arsenic compounds. Output from the former began in May, 1918, but bulk production was not reached until November, 1918. The total output was 60 tons. In July, 1918, H.M. Factory, Ellesmere Port, was expected to have a capacity of 40 tons weekly, and in view of the urgency of the demand, military labour was employed to hasten both the construction and the operation of the new plant. Nevertheless, actual output fell far below the estimated capacity. A small factory at Rainham, belonging to the South Metropolitan Gas Company, was brought under the direct control of the Ministry during the summer of 1918, and was converted for the production of arsenic compounds, at a total cost of £40,200.

The largest national factory which was established for chemical manufacture at this time was H.M. Factory, Avonmouth, which was originally planned as a picric acid factory, and was turned over to the production of mustard gas, in June, 1918.[2] As a part of the same scheme for the manufacture of large quantities of mustard gas, the erection of an agency factory at Langley was begun in the spring of 1918, for producing the solvent, carbon tetrachloride. This factory was completed and operations began in September, 1918, although benzol had replaced carbon tetrachloride as a solvent in mustard gas manufacture, and the output of the factory was subsequently intended for naval purposes and for satisfying French demands, which would otherwise have been met in chlorine.[3] The capital expenditure on this factory was about £117,300.

In August, 1918, steps were taken to nationalise the works of Messrs. Electro Bleach and By-Products, Ltd.,[4] at Middlewich, owing to the unsatisfactory nature of their output. The company had erected this factory in 1917, on land adjoining their existing works, and the capital outlay had been borne by the State. The new factory had then been laid out for the manufacture and charging of 10 tons of phosgene.and the liquefaction of 20 tons of gaseous chlorine per week. When it was taken over in 1918, it proved impracticable to make an absolute distinction between the national plant and the firms' works, from which power, light and transport facilities were derived, but the thorough re-organisation which followed the establishment of direct control over the poison-gas factory resulted in a very greatly increased output and a higher standard of work. From August to November, 1918, the output of phosgene was raised from an average of about three tons weekly to a quantity little less than the full estimated capacity of 10 tons weekly, while the proportion of the charged shells which were rejected on inspection was reduced from 7 per cent. to 5 per cent.

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[1] HIST. REC./H/1122/13.
[2] For an account of this factory, *see* above p. 49.
[3] X/CW/709.
[4] HIST. REC./H/1122.7/14.

Owing to the peculiar nature of the work upon poison-gas manufacture, the employment of skilled men of good physique was imperative, and the dilution of labour was difficult. In the autumn of 1918, the total numbers employed in State factories for the production of lethal substances, were 1,422, of whom 244 alone were women. This figure excluded the comparatively small factories at Rainham and Langley.

National Factories for Gas-charging.

Owing to the difficulty of transporting poisonous substances, the work of charging them into shell was undertaken, wherever possible, at the place of manufacture. The first separate venture for the charging of projectiles was the trade factory established at Walthamstow in 1915, and subsequently nationalised. For a considerable period, it was engaged also upon the head-filling of chemical shell, of which work an account has already been given.[1] Messrs. Ardol's factory at Selby,[2] was taken over by the Ministry in June, 1916, and carried out shell charging and the production of hydrogen and hydrogenated oils. This factory was not brought under direct control but was administered under an agency agreement.

In addition to the British factories, plant was set up at Calais in March, 1916, for charging phosgene, supplied by the French, into cylinders, 3,400 cylinders being delivered weekly. The charging factory was worked at first by from 30 to 40 English civilians, and subsequently by a military party from the Special Brigade under the supervision of an official of the Chemical Supply Section.

Owing to the undesirability of introducing explosives into the factories where the chemicals were manufactured and charged, the process known as filling, *i.e.*, the insertion of the bursting-charge into the shells already charged with chemicals, was not undertaken as a rule by contractors or national chemical factories, but the charged shell were sent to Greenford,[3] where a factory was erected in 1916, solely for the filling and assembling of chemical shell.

Spare capacity in the National Filling Factories was adapted towards the end of the war for the charging of shells with mustard-gas as well as for the head-filling and assembling of these and other chemical shells. From July to November, 1918, 85,424 6-in. shells were charged at the factory which was specially erected for this purpose at Chittening, and 82,000 4·5-in. and 220,000 18-pdr. shells were charged at Banbury. The Hereford Filling Factory began charging in October, 1918, and completed 3,000 4·5-in. and 1,000 18-pdr. shells by November. At Chittening the filling, as well as the charging, of shell was undertaken, but most of the shell charged at Banbury and Hereford were sent to Hayes National Filling Factory to be filled. The work carried out in the filling factories has already been described.[4]

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[1] *See* above p. 184.
[2] D.E.S./C.W./169; T.W. 6161.
[3] *See* above p. 183.
[4] *See* above p. 156.

The Salvage Depôt, Bucknall.

It was eventually found necessary to nationalise the depôt, which was engaged in recovering chemicals from returned and rejected cylinders, since the operations involved were peculiarly difficult and entirely experimental and the irregularity of the work hampered the settlement of contract terms. The risk of injury to the workers, through escapes of gas, was also peculiarly great. The depôt had been established in 1916, by the Bucknall Sawmills Company. The capital expenditure was borne by the Ministry, and the depôt was operated under an agency agreement until June, 1917. It was brought under direct control in July, 1917, with a view to increasing efficiency and economy. The capital expenditure on the depôt down to March, 1919, was £11,500.

National Factories for Anti-Gas Apparatus.

The first committees appointed, after the German gas offensive in April, 1915, to deal with supplies of defensive apparatus, placed all the work with contractors, and no national factory was established until late in 1916, although a certain amount of cutting and sewing was carried out in factories controlled by the Royal Army Clothing Department. The first anti-gas factory to be set up directly under Government control was at Stamford Hill, where the L.C.C. Stores Depôt was acquired in 1916, and fitted up as a granule factory on the model of Messrs. Boot's factory at Nottingham. Before production started a new formula was introduced, and further plant was erected to produce the new F. granule. In February, 1917, the factory started operations under the control of the Anti-Gas Department (then a section of the War Office and subsequently transferred to the Ministry), and continued until the Armistice, the maximum output obtained from a day and night shift being 30 tons weekly. In August, 1918, the Ministry opened new factories at Batavia Mills and Holloway Mills, Holloway, which were directly controlled by the Department, for the manufacture of "Green-Band" respirators, the total number produced by 11 November being 55,140, in addition to a large number of spare parts.

Although the national works which were actually established for the manufacture of anti-gas apparatus were thus strictly limited in number, a very great part of the production took place in numerous factories which were controlled by two firms under contracts which very nearly approached the form of an agency agreement. These firms, Messrs. John Bell, Hill and Lucas, and Messrs. James Spicer and Sons, not only manufactured apparatus and components in their own factories, but also supervised production by a large number of contractors' works, mostly in the neighbourhood of London.[1]

The following list shows the national factories which were actually employed on chemical or anti-gas work, with the exception of inspection

[1] For a detailed account of their work, *see* Vol. XI, Part II, Chap. VI.

and storage depôts controlled by the Anti-Gas Department, where a certain amount of minor work, such as repairing, took place.

Factory.	Purpose.	Date.[1]
Manufacture of Chemical Substances.		
H.M. Explosives Factory, Sutton Oak.	Arsenic Compounds ..	March, 1918. (*See* above p. 76.)
H.M. Explosives Factory, Ellesmere Port.	Arsenic Compounds ..	July, 1918. (*See* above p. 54.)
H.M. Explosives Factory, Avonmouth.	Mustard Gas	June, 1918. (*See* above p. 49.)
H.M. Factory, Langley ..	Carbon tetrachloride ..	1918.
H.M. Factory, Middlewich..	Manufacture and charging of phosgene; liquefaction of chlorine.	August, 1918.
H.M. Factory, Rainham ..	Manufacture of arsenic compounds.	1918.
Charging with Chemical Substances.		
T.W. National Factory, Walthamstow.	Charging lachrymatory grenades, shells and projector-drums; head-filling lethal shells.	June, 1916. (*See* above p. 184.)
T.W. Factory, Calais ..	Charging cylinders and projector-drums.	March, 1916.
T.W. Factory, Selby (Ardol, Ltd.).	Charging Russian shell.	June, 1916.
H.M. Factory, Chittening ..	Charging and head filling mustard gas shells.[2]	1918. (*See* above p. 181.)
National Filling Factory, Banbury.	Charging and head filling and assembling mustard gas shells.[2]	1918. (*See* above p. 159.)
National Filling Factory, Hereford.	Charging and head filling and assembling mustard gas shells.[2]	October, 1918. (*See* above p. 167.)
Salvage.		
Bucknall Cylinder Depot ..	Evacuating and refitting cylinders.	July, 1917.
Manufacture of Anti-Gas Apparatus.		
L.C.C. Stores Depot, Stamford Hill.	Producing granules ..	1916.
Batavia Mills, Holloway ..	Making "Green Band" Respirators.	August, 1918.
Holloway Mills, Holloway ..	Making "Green Band" Respirators.	August, 1918.

IX. The National Rifle Factories at Birmingham.[3]

Two national factories for the manufacture of the Farquahar-Hill automatic rifle were established at Birmingham in 1918. The National Rifle Factory No. 1 consisted of buildings in Lench Street, the main

[1] Of erection, nationalisation or conversion to chemical work.

[2] For the factories engaged solely upon head-filling or assembling chemical shells, *see* above p. 156.

[3] M.C. 680; D.D.G.E./E.M. 3/1009; D.D.G.E./E.M. 9/75.

part of which was originally a small arms factory operated by the Standard Small Arms Company in connection with the component pool for rifle manufacture. It also included premises on the opposite side of the road, which had originally been built as an extension to the company's shops and afterwards taken over by the Ministry of Munitions as a training school. The National Rifle Factory No. 2 was in Garrison Lane and had been built shortly before by Messrs. W. Greener for the manufacture of rifle-parts. A definite request for 100,000 Farquahar-Hill rifles was made by the Army Council on 3 May, 1918. It was immediately decided that manufacture should be carried out on a peddled scheme, that the Lench Street Factory should make the more complicated parts and assemble the rifles, and the Garrison Lane Factory should make the barrels upon plant already existing there and to be removed thither from Lench Street.

Rifle manufacture requires special skill and experience, and until this date the production of complete weapons had been confined to the Royal Small Arms Factory at Enfield and experienced contractors. The supply of the new automatic rifle involved experimental manufacture, normally undertaken at Enfield ; but circumstances made any further extension of that factory difficult, its utilization would have seriously affected the output of standard rifles, and its situation within the air-raid district made any expansion of its work undesirable. Most of the contractors engaged upon rifle and machine-gun manufacture were either unsuited for the new work or fully occupied. No complete drawings, and only one model rifle existed. The Standard Small Arms Company was peculiarly fitted to undertake the main part of the work, not only by reason of its experience in manufacturing for the component pool, but because the managing director had produced the first Farquahar-Hill rifles made and the company had assembled those of recent manufacture.

The scheme had necessarily to be financed by the Ministry, and an exact agreement was impossible to negotiate for so complex and novel a weapon. Accordingly, it was decided to purchase the factories from the two companies and operate them as national factories. Agreements as to the management were the subject of lengthy negotiation ; but it was considered undesirable to take over the premises under the Defence of the Realm Act lest the goodwill of the management should be alienated. The general uncertainty as to the position seriously militated against enthusiasm and the operatives at the two factories became restless during the summer. Finally, on 16 October, 1918, the Army Council cancelled its demand for these rifles, in view of the impossibility of obtaining output in time to train the troops for the spring campaign. Steps were accordingly taken to close down the factories before any definite output had been attained. The capital expenditure upon both factories amounted to £166,500 by March, 1919.

APPENDICES.

APPENDIX I.

(CHAPTER III.)

Output of Empty Shell from National Shell Factories.

[Figures in Thousands.]

	1915.	1916.	1917.	1918.	Total.
Aberdeen—					
6-in. H.E.	—	—	34·6	65·1	99·7
Total	—	—	34·6	65·1	99·7
Ailsa Craig—					
4·5-in. H.E.	—	—	115·0	138·2	253·2
Total	—	—	115·0	138·2	253·2
Barnsley—					
4·5-in. H.E.	—	56·2	143·5	104·9	304·6
Total	—	56·2	143·5	104·9	304·6
Birmingham—					
18-pdr. H.E.	—	35·5	15·0	6·5	57·0
4·5-in. H.E.	—	296·6	687·0	752·7	1,736·3
9·2-in. H.E.	—	—	27·0	22·2	49·2
Total	—	332·1	729·0	781·4	1,842·5
Bradford—					
4·5-in. H.E.	14·0	180·0	247·6	212·4	654·0
4·5-in. Chemical ..	—	1·2	22·6	—	23·8
Total	14·0	181·2	270·2	212·4	677·8
Bristol—					
18-pdr. H.E.	39·4	858·5	1,111·2	1,024·1	3,033·2
18-pdr. S.	—	—	—	167·2	167·2
Total	39·4	858·5	1,111·2	1,191·3	3,200·4
Bury—					
18-pdr. Smoke ..	—	—	—	31·5	31·5
4·5-in. H.E.	—	9·5	32·9	69·5	111·9
Total	—	9·5	32·9	101·0	143·4
Cardiff—					
18-pdr. H.E.	3·2	35·2	187·2	272·3	497·9
Total	3·2	35·2	187·2	272·3	497·9
Cork—					
4·5-in. H.E.	—	—	10·4	21·8	32·2
Total	—	—	10·4	21·8	32·2

APPENDIX I—*contd.*

	1915.	1916.	1917.	1918.	Total.
Derby—					
4·5-in. H.E.	·4	150·0	258·4	137·5	546·3
4·7-in. Chemical ..	—	—	3·4	—	3·4
Total	·4	150·0	261·8	137·5	549·7
Dublin—					
18-pdr. H.E.	—	113·8	230·8	180·7	525·3
18-pdr. Smoke ..	—	—	—	12·4	12·4
9·2-in. H.E.	—	—	2·4	3·7	6·1
Total	—	113·8	233·2	196·8	543·8
Dundee—					
18-pdr. H.E.	11·5	201·8	339·1	8·7	561·1
2·75-in. S.	—	1·3	3·0	—	4·3
Total	11·5	203·1	342·1	8·7	565·4
E. Cumberland (Carlisle)—					
18-pdr. H.E.	—	40·5	99·5	164·6	304·6
18-pdr. Smoke ..	—	—	1·8	·2	2·0
Total	—	40·5	101·3	164·8	306·6
Ebbw Vale—					
18-pdr. H.E.	6·7	82·5	—	—	89·2
Total	6·7	82·5	—	—	89·2
Galway—					
18-pdr. H.E.	—	—	11·7	21·9	33·6
Total	—	—	11·7	21·9	33·6
Grimsby—					
4·5-in. H.E.	—	—	—	16·5	16·5
6-in. H.E.	1·0	65·9	143·2	108·2	318·3
Total	1·0	65·9	143·2	124·7	334·8
Hartlepool (Tyne and Wear)—					
8-in. H.E.	—	14·7	66·4	—	81·1
Total	—	14·7	66·4	—	81·1
Huddersfield—					
18-pdr. H.E.	3·1	64·3	182·7	220·0	470·1
Total	3·1	64·3	182·7	220·0	470·1

APPENDIX I—*contd.*

	1915.	1916.	1917.	1918.	Total.
Keighley—					
18-pdr. H.E.	23·6	188·3	127·6	149·1	488·6
18-pdr. Chemical ..	—	—	—	131·3	131·3
3·7-in. H.E.	—	—	140·3	11·9	152·2
6-pdr. A.A.	—	19·1	2·1	—	21·2
Total	23·6	207·4	270·0	292·3	793·3
Leeds—See under National Projectile Factories.					
Liverpool[1]—					
18-pdr. H.E.	45·3	746·4	562·5	500·2	1,854·4
18-pdr. Chemical ..	—	—	—	1·0	1·0
18-pdr. Smoke ..	—	—	10·5	8·0	18·5
2·75-in. H.E. ..	—	24·7	296·0	476·6	797·3
4·5-in. H.E.	—	18·1	28·0	—	46·1
60-pdr. H.E.	—	—	6·6	—	6·6
6-in. H.E.	—	52·5	187·0	192·4	431·9
8-in. H.E.	—	—	13·9	12·7	26·6
Total	45·3	841·7	1,104·5	1,190·9	3,182·4
Llanelly—					
18-pdr. H.E.	—	—	75·9	430·0	505·9
6-in. H.E.	—	44·4	256·1	364·9	665·4
Total	—	44·4	332·0	794·9	1,171·3
Manchester—					
4·5-in. H.E.	—	8·0	29·1	51·8	88·9
Total	—	8·0	29·1	51·8	88·9
Newport—					
60-pdr. H.E.	—	133·5	298·6	169·1	601·2
Total	—	133·5	298·6	169·1	601·2
North Wales[2]—					
13-pdr. H.E.	—	—	44·0	10·6	54·6
18-pdr. H.E.	—	22·7	318·1	490·6	831·4
18-pdr. Smoke ..	—	—	5·0	4·0	9·0
Total	—	22·7	367·1	505·2	895·0
Nottingham—					
13-pdr. H.E.	9·4	324·3	13·1	—	346·8
18-pdr. H.E.	—	—	543·3	564·1	1,107·4
18-pdr. Smoke ..	—	—	—	1·9	1·9
2·75-in. H.E. ..	—	46·7	7·3	—	54·0
Total	9·4	371·0	563·7	566·0	1,510·1

[1] Includes Haymarket, Cunard, Lambeth Road, and Chester.

[2] Includes Wrexham, Portmadoc, and Carnarvon.

APPENDIX I—*contd.*

	1915.	1916.	1917.	1918.	Total.
Rawtenstall and Bacup—					
4·5-in. H.E.	—	15·9	61·4	79·6	156·9
Total	—	15·9	61·4	79·6	156·9
Rochdale—					
6-in. H.E.	—	10·9	39·8	39·5	90·2
Total	—	10·9	39·8	39·5	90·2
Rotherham—					
4·5-in. H.E.	·7	82·6	156·9	174·2	414·4
4·5-in. Chemical ..	—	—	10·5	—	10·5
Total	·7	82·6	167·4	174·2	424·9
Swansea—					
18-pdr. H.E.	2·7	76·5	80·2	55·7	215·1
4·5-in. H.E.	—	51·4	198·0	170·5	419·9
Total	2·7	127·9	278·2	226·2	635·0
Uskside—					
18-pdr. H.E.	2·1	21·0	1·4	—	24·5
4·5-in. H.E.	—	—	—	16·1	16·1
6-in. H.E.	—	21·8	55·4	42·5	119·7
Total	2·1	42·8	56·8	58·6	160·3
W. Cumberland—					
18-pdr. H.E.	—	38·2	146·3	167·9	352·4
18-pdr. Smoke ..	—	—	3·5	3·5	7·0
Total	—	38·2	149·8	171·4	359·4
Totals—					
13-pdr. H.E.	9·4	324·3	57·1	10·6	401·4
18-pdr. H.E.	137·6	2,525·2	4,032·5	4,256·4	10,951·7
18-pdr. S.	—	—	—	167·2	167·2
18-pdr. Chemical ..	—	—	—	132·3	132·3
18-pdr. Smoke ..	—	—	20·8	61·5	82·3
2·75-in. H.E. ..	—	64·8	35·3	—	100·1
2·75-in. S.	—	1·3	3·0	—	4·3
3·7-in. H.E.	—	—	140·3	11·9	152·2
6-pdr. A.A.	—	19·1	2·1	—	21·2
4·7-in. Chemical ..	—	—	3·4	—	3·4
60-pdr. H.E.	—	133·5	305·2	169·1	607·8
4·5-in. H.E.	15·1	874·9	2,236·2	2,353·9	5,480·1
4·5-in. Chemical ..	—	1·2	33·1	—	34·3
6-in. H.E.	1·0	195·5	716·1	812·6	1,725·2
8-in. H.E.	—	14·7	80·3	12·7	107·7
9·2-in. H.E.	—	—	29·4	25·9	55·3
Grand Total ..	163·1	4,154·5	7,694·8	8,014·1	20,026·5

APPENDIX II.

(Chapter IV.)

Output of Empty Shell from National Projectile Factories.

[Figures in Thousands.]

	1915.	1916.	1917.	1918.	Total.
Birtley—					
4-in. H.E.	—	—	—	16·2	16·2
60-pdr. S.	—	44·1	145·9	271·0	461·0
4·5-in. H.E.	—	—	171·0	228·3	399·3
6-in. H.E.	—	93·9	507·9	690·2	1,292·0
8-in. H.E.	—	27·2	296·6	313·5	637·3
Total	—	165·2	1,121·4	1,519·2	2,805·8
Cardonald—					
18-pdr. H.E.	—	—	50·7	0·2	50·9
6-in. Chemical ..	—	—	—	319·8	319·8
8-in. H.E.	—	162·5	466·6	379·0	1,008·1
Total	—	162·5	517·3	699·0	1,378·8
Cathcart—					
8-in. H.E.	—	44·4	49·8	—	94·2
Total	—	44·4	49·8	—	94·2
Darlington—					
18-pdr. S.	—	—	454·4	609·4	1,063·8
6-in. H.E.	—	14·8	44·9	57·0	116·7
Total	—	14·8	499·3	666·4	1,180·5
Dudley—					
18-pdr. H.E.	—	—	35·8	1·4	37·2
60-pdr. S.	—	247·3	582·1	611·8	1,441·2
6-in. H.E.	—	77·8	250·4	3·3	331·5
6-in. Chemical ..	—	—	105·1	544·2	649·3
Total	—	325·1	973·4	1,160·7	2,459·2
Hackney Marshes—					
6-in. H.E.	—	236·6	418·1	380·5	1,035·2
6-in. Chemical ..	—	—	—	346·5	346·5
Total	—	236·6	418·1	727·0	1,381·7

Appendix II—*contd.*

	1915.	1916.	1917.	1918.	Total.
Lancaster—					
60-pdr. S.	—	139·0	252·2	198·3	589·5
6-in. H.E.	—	30·8	254·5	474·0	759·3
6-in. Chemical ..	—	—	—	234·6	234·6
8-in. H.E.	—	—	9·4	0·2	9·6
9·2-in. H.E.	—	69·2	204·0	174·8	448·0
Total	—	239·0	720·1	1,081·9	2,041·0
Leeds[1]—					
4·5-in. H.E.	37·3	105·2	1·5	—	144·0
6-in. H.E.	—	167·7	394·1	430·4	992·2
8-in. H.E.	—	—	8·6	5·2	13·8
9·2-in. H.E.	—	66·6	191·8	172·9	431·3
12-in. H.E.	—	—	0·1	6·5	6·6
15-in. H.E.	—	1·4	4·6	1·3	7·3
Total	37·3	340·9	600·7	616·3	1,595·2
Mile End (Glasgow)—					
18-pdr. H.E... ..	—	—	378·2	81·6	459·8
60-pdr. H.E... ..	—	136·1	197·3	346·2	679·6
6-in. H.E.	—	108·3	399·4	335·4	843·1
6-in. Chemical ..	—	—	—	25·7	25·7
Total	—	244·4	974·9	788·9	2,008·2
Nottingham—					
6-in. H.E.	—	134·9	433·5	115·9	684·3
9·2-in. H.E.	—	73·3	136·8	—	210·1
Total	—	208·2	570·3	115·9	894·4
Ponders End—					
6-in. H.E.	—	—	113·8	180·8	294·6
8-in. H.E.	—	—	126·5	173·2	299·7
12-in. H.E.	—	—	·7	—	·7
Total	—	—	241·0	354·0	595·0
Renfrew—					
60-pdr. S.	—	97·1	179·1	369·5	645·7
9·2-in. H.E.	—	—	36·9	27·4	64·3
12-in. H.E.	—	4·9	1·2	—	6·1
Total	—	102·0	217·2	396·9	716·1
Sheffield (Hadfield)—					
9·2-in. H.E.	—	119·0	167·1	3·1	289·2
Total	—	119·0	167·1	3·1	289·2

[1] Includes Armley, Newlay and Hunslet.

Appendix II—*contd.*

	1915.	1916.	1917.	1918.	Total.
Sheffield (Firth)—					
60-pdr. H.E.	—	355·7	618·3	701·9	1,675·9
60-pdr. Chemical ..	—	—	—	166·9	166·9
4·5-in. H.E.	—	—	411·3	239·2	650·5
4·5-in. Chemical ..	—	—	—	115·8	115·8
Total	—	355·7	1,029·6	1,223·8	2,609·1
Totals—					
18-pdr. H.E.	—	—	464·7	83·2	547·9
18-pdr. S.	—	—	454·4	609·4	1,063·8
4-in. H.E.	—	—	—	16·2	16·2
4·5-in. H.E.	37·3	105·2	583·8	535·9	1,262·2
4·5-in. Chemical ..	—	—	—	115·8	115·8
60-pdr. H.E.	—	491·8	815·6	1,048·1	2,355·5
60-pdr. S.	—	527·5	1,159·3	1,450·6	3,137·4
60-pdr. Chemical ..	—	—	—	166·9	166·9
6-in. How. H.E. ..	—	864·8	2,816·6	2,667·5	6,348·9
6-in. How. Chemical..	—	—	105·1	1,470·8	1,575·9
8-in. H.E.	—	234·1	957·5	871·1	2,062·7
9·2-in. H.E.	—	328·1	736·6	378·2	1,442·9
12-in. H.E.	—	4·9	2·0	6·5	13·4
15-in. H.E.	—	1·4	4·6	1·3	7·3
Grand Total ..	37·3	2,557·8	8,100·2	9,421·5	20,116·8

APPENDIX III.

(CHAPTER V.)

Output of Filled Shell from National Filling Factories.

[Figures in Thousands.]

	1915.	1916.	1917.	1918.	Total.
Banbury—					
18-pdr. Chemical ..	—	—	—	250·6	250·6
6-pdr. C.P.	—	—	—	225·6	225·6
60-pdr. H.E.	—	228·1	490·4	103·7	822·2
60-pdr. S.	—	—	—	608·6	608·6
4·5-in. Chemical ..	—	—	—	93·4	93·4
6-in. Gun S.	—	—	—	67·0	67·0
6-in. How. H.E. ..	—	25·6	848·2	189·1	1,062·9
6-in. Chemical ..	—	—	—	387·0	387·0
8-in. H.E.	—	5·3	—	10·9	16·2
9·2-in. How. H.E. ..	—	131·8	197·8	2·5	332·1
Total	—	390·8	1,536·4	1,938·4	3,865·6
Chilwell—					
60-pdr. H.E.	—	667·0	1,435·0	918·1	3,020·1
4·5-in. H.E.	—	45·0	—	—	45·0
6-in. Gun H.E. ..	—	—	27·2	227·7	254·9
6-in. How. H.E. ..	—	1,196·4	4,200·6	5,762·2	11,159·2
9·2-in. Gun H.E. ..	—	—	—	8·9	8·9
8-in. H.E.	—	541·2	1,433·0	952·8	2,927·0
9·2-in. How. H.E. ..	—	555·7	1,005·1	192·2	1,753·0
12-in. How. H.E. ..	—	43·1	67·1	52·3	162·5
15-in. H.E.	—	1·1	5·9	5·1	12·1
Total	—	3,049·5	8,173·9	8,119·3	19,342·7
Chittening—					
6-in. How. Chemical..	—	—	—	86·4	86·4
Total	—	—	—	86·4	86·4
Devonport—					
18-pdr. S. completing foreign	47·6	1,963·1	1,046·3	—	3,057·0
Total	47·6	1,963·1	1,046·3	—	3,057·0

APPENDIX III—*contd.*

	1915.	1916.	1917.	1918.	Total.
Georgetown—					
18-pdr. H.E.	—	1,218·1	2,942·6	3,784·4	7,945·1
,, completing foreign	—	41·5	—	—	41·5
18-pdr. S.	—	1,130·2	2,004·3	1,958·5	5,093·0
13-pdr. (9-cwt.) H.E.	—	—	19·9	420·9	440·8
3-in. (20-cwt.) H.E. ..	—	—	—	114·8	114·8
18-pdr. H.E. A.A. ..	—	—	4·6	·3	4·9
60-pdr. S.	—	154·6	376·6	123·1	654·3
4·5-in. H.E.	—	220·1	1,607·8	1,070·5	2,898·4
4·5-in. S.	—	6·4	—	—	6·4
6-in. How. H.E. ..	—	32·0	538·6	1,469·8	2,040·4
9·2-in. H.E.	—	—	—	7·7	7·7
12-in. H.E.	—	—	24·8	21·1	45·9
Total	—	2,802·9	7,519·2	8,971·1	19,293·2
Gloucester—					
18-pdr. H.E.	—	195·2	2,024·9	1,089·7	3,309·8
,, completing foreign	—	1,022·1	181·2	—	1,203·3
18-pdr. S.	—	766·9	1,449·9	3,404·7	5,621·5
,, completing foreign	—	18·7	73·1	55·6	147·4
60-pdr. S.	—	17·6	—	—	17·6
Total	—	2,020·5	3,729·1	4,550·0	10,299·6[1]
Hayes—					
18-pdr. H.E.	—	—	1,390·1	881·5	2,271·6
,, completing foreign	10·6	1,888·5	806·4	—	2,705·5
18-pdr. S.	—	113·4	885·4	776·8	1,775·6
,, completing foreign	15·4	37·2	—	—	52·6
60-pdr. H.E.	—	73·5	13·1	—	86·6
4·7-in. H.E.	—	23·3	—	—	23·3
4·5-in. H.E.	—	1,245·9	1,777·6	1,831·9	4,855·4
6-in. Gun S.	—	—	—	37·8	37·8
6-in. How. H.E. ..	—	87·6	177·8	307·0	572·4
12-in. H.E.	—	—	·2	—	·2
Total	26·0	3,469·4	5,050·6	3,835·0	12,381·0
Hereford—					
18-pdr. Chemical ..	—	—	—	1·0	1·0
60-pdr. H.E.	—	—	—	291·2	291·2
6-in. How. H.E. ..	—	6·8	778·4	877·4	1,662·6
6-in. How. Chemical..	—	—	—	61·2	61·2
8-in. H.E.	—	—	368·6	839·1	1,207·7
9·2-in. How. H.E. ..	—	—	119·2	827·5	946·7
Total	—	6·8	1,266·2	2,897·4	4,170·4
Horley—					
18-pdr. S. completing foreign	—	3,158·5	1,578·6	—	4,737·1
Total	—	3,158·5	1,578·6	—	4,737·1

[1] Exclusive of 384, 269 4·5in. shell filled and assembled at Gloucester N.F.F.

APPENDIX III—*contd.*

	1915.	1916.	1917.	1918.	Total.
Leeds—					
18-pdr. H.E.	—	949·4	3,096·5	5,012·1	9,058·0
,, completing foreign	—	4·8	—	—	4·8
18-pdr. S.	—	321·7	—	—	321·7
,, completing foreign	—	10·6	—	—	10·6
60-pdr. H.E.	—	6·6	—	—	6·6
60-pdr. S.	—	2·0	142·9	39·5	184·4
4·5-in. H.E.	—	2,939·0	6,040·9	4,328·7	13,308·6
6-in. How. H.E. ..	—	277·2	362·7	1,035·1	1,675·0
Total	—	4,511·3	9,643·0	10,415·4	24,569·7
Liverpool—					
18-pdr. H.E.	—	418·7	2,539·2	1,118·6	4,076·5
,, completing foreign	—	1,092·4	257·1	—	1,349·5
18-pdr. S.	—	855·5	2,623·3	3,387·4	6,866·2
,, completing foreign	—	9·5	—	—	9·5
18-pdr. incendiary ..	—	—	—	39·0	39·0
60-pdr. H.E.	—	·2	12·7	373·1	386·0
60-pdr. S.	—	26·2	—	—	26·2
4·5-in. H.E.	—	89·2	6·5	—	95·7
4·5-in. S.	—	10·0	15·6	—	25·6
5-in. H.E.	—	—	125·6	—	125·6
6-in. How. H.E. ..	—	184·6	1,562·4	2,467·9	4,214·9
8-in. H.E.	—	—	61·2	64·2	125·4
Total	—	2,686·3	7,203·6	7,450·2	17,340·1
Morecambe—					
60-pdr. H.E.	—	—	117·9	—	117·9
6-in. How. H.E. ..	—	368·3	1,826·7	—	2,195·0
8-in. H.E.	—	17·7	291·0	—	308·7
9·2-in. How. H.E. ..	—	18·9	242·9	—	261·8
12-in. H.E.	—	6·3	3·4	—	9·7
Total	—	411·2	2,481·9	—	2,893·1
Watford Nos. 1 *and* 2, *and Greenford*—					
60-pdr. Chemical ..	—	—	580·9	63·8	644·7
4·5-in. Chemical ..	—	18·0	954·7	1,137·3	2,110·0
4·5-in. Smoke ..	—	—	118·5	349·2	467·7
6-in. How. Chemical..	—	—	49·8	774·4	824·2
Total	—	18·0	1,703·9	2,324·7	4,046·6

Appendix III—*contd.*

	1915.	1916.	1917.	1918.	Total.
Totals—					
18-pdr. H.E.	10·6	6,830·7	13,238·0	11,886·3	31,965·6
18-pdr. S.	63·0	8,385·3	9,660·9	9,583·0	27,692·2
18-pdr. Chemical ..	—	—	—	251·6	251·6
18-pdr. Incendiary ..	—	—	—	39·0	39·0
13-pdr. (9-cwt.) H.E.	—	—	19·9	420·9	440·8
3-in. (20-cwt.) H.E. ..	—	—	—	114·8	114·8
18-pdr. A.A. H.E. ..	—	—	4·6	·3	4·9
6-pdr. C.P.	—	—	—	225·6	225·6
60-pdr. H.E.	—	975·4	2,069·1	1,686·1	4,730·6
60-pdr. S.	—	200·4	519·5	771·2	1,491·1
60-pdr. Chemical ..	—	—	580·9	63·8	644·7
4·7-in. H.E.	—	23·3	—	—	23·3
4·5-in. H.E.	—	4,539·2	9,432·8	7,231·1	21,203·1
4·5-in. S.	—	16·4	15·6	—	32·0
4·5-in. Chemical ..	—	18·0	954·7	1,230·7	2,203·4
4·5-in. Smoke ..	—	—	118·5	349·2	467·7
5-in. H.E.	—	—	125·6	—	125·6
6-in. Gun H.E. ..	—	—	27·2	227·7	254·9
6-in. Gun S.	—	—	—	104·8	104·8
6-in. How. H.E. ..	—	2,178·5	10,295·4	12,108·5	24,582·4
6-in. How. Chemical..	—	—	49·8	1,309·0	1,358·8
9·2-in. Gun. H.E. ..	—	—	—	8·9	8·9
8-in. How. H.E. ..	—	564·2	2,153·8	1,867·0	4,585·0
9·2-in. How. H.E. ..	—	706·4	1,565·0	1,029·9	3,301·3
12-in. H.E.	—	49·4	95·5	73·4	218·3
15-in. H.E.	—	1·1	5·9	5·1	12·1
Grand Total ..	73·6	24,488·3	50,932·7	50,587·9	126,082·5[1]

[1] Exclusive of 384,269 4·5-in. shell filled and assembled at Gloucester N.F.F.

APPENDIX IV.

Chronological Schedule of the National Factories controlled by the Ministry of Munitions, June, 1915, to November, 1918.

Key to Abbreviations :

H.M.E.F. = H.M. Explosives Factory.
N.S.F. = National Shell Factory.
N.P.F. = National Projectile Factory.
N.O.F. = National Ordnance Factory.
N.F.F. = National Filling Factory.
T.W.F.F. = Trench Warfare Filling Factory.
G.C.F. = Government Cartridge Factory.
N.A.F. = National Aircraft Factory.

(*c*) After the date signifies date of construction or equipment as a national factory ; (*n*) Signifies date of nationalisation of an existing trade factory. Where a factory was administered under an agency agreement the name of the firm which acted as agent is given. Figures marked * represent capital expenditure to 31 March, 1919.

Name and Address of Factory.	Class of Factory.	Date of Initiation.	Date of First Output.	Output.	Form of Administration.	Capital Expenditure to 31/3/18.*
						£
1. *Woolwich*, Royal Arsenal[1]	Royal Ordnance Factory.	*c* 1695 (*c*)	—	Making and repairing guns and carriages ; making, filling and assembling shell and components ; making small arms, ammunition, &c.	Direct Control ..	—
2. *Waltham Abbey*, Royal Gunpowder Factory[1]	Royal Ordnance Factory.	1787 (*n*)	—	Cordite, gunpowder, tetryl, guncotton and fuse powder.	Direct Control ..	—
3. *Enfield Lock*, Royal Small Arms Factory[1]	Royal Ordnance Factory.	1804 (*c*)	—	Rifles, machine guns, and small arms..	Direct Control ..	—
4. *Farnborough* [Hants][2]	Royal Aircraft Establishment.	1905 (*c*)	—	Aircraft and aircraft materials (mainly experimental work).	Direct Control ..	—
5. *Coleford* [Glos.][3]	H.M.E.F.	1913 (*c*)	—	Producing acetate of lime by wood distillation.	Direct Control ..	40,900
6. *Rainham* [Essex][4]	H.M.E.F.	Nov., 1914 (*c*)	Jan., 1915	Purifying crude T.N.T...	(*a*) Coley & Wilbraham ; (*b*) Direct Control.	35,000
7. *Oldbury* [Worcs.]	H.M.E.F.	Jan., 1915 (*c*)	May, 1915	T.N.T.	Chance & Hunt ..	835,300*
8. *Queen's Ferry* [nr. Chester] ..	H.M.E.F.	May, 1915 (*c*)	Dec., 1915	Guncotton, T.N.T. and tetryl ..	Direct Control ..	3,430,300
9. *Bideford* [Devon][3]	H.M.E.F.	*c* May, 1915 (*c*)	—	Producing acetate of lime by wood distillation.	Direct Control ..	48,100
10. *Dundee*, Graham Street[3]	H.M.E.F.	*c* May, 1915 (*c*)	—	Producing acetate of lime by wood distillation.	Direct Control ..	19,100
11. *Leeds*, Armley Road[5]	N.S.F., N.P.F., N.O.F.	May, 1915 (*c*)	Sept., 1915	4·5-in. and 6-in. shell ; repair and inspection of guns (1917–18).	Board of Management.	248,400

[1] Transferred from War Office, August, 1915. [2] Transferred from War Office, November, 1916. [3] Transferred from Office of Woods and Forests, October, 1915.
[4] Destroyed by fire, February, 1918. [5] Classed as N.P.F. 1916–17, N.O.F. 1917–18.

Name and Address of Factory.	Class of Factory.	Date of Initiation.	Date of First Output.	Output.	Form of Administration.	Capital Expenditure to 31/3/18*
						£
12. *Keighley No.* 1, Dalton Lane ..	N.S.F.	May, 1915 (*c*)	Autumn, 1915	18-pdr., 3·7-in. and 6-pdr. (A.A.) shell	Board of Management.	51,200
13. *Birmingham*, Midland Works, Washwood Heath.	N.S.F.	June, 1915 (*c*)	Feb., 1916	Making and completing 18-pdr. and 4·5-in. shell.	Board of Management.	187,600
14. *Bradford*, Valley Road	N.S.F.	June, 1915 (*c*)	Nov., 1915	4·5-in. shell, fuses, gaines, &c., completing 4·5-in. shell.	Board of Management.	56,700
15. *Bristol*, Victoria Road	N.S.F.	June, 1915 (*c*)	Early, 1916	Completing and rectifying 18-pdr. shell	Board of Management.	20,000
16. *Derby*, Peel Foundry	N.S.F.	June, 1915 (*c*)	Dec., 1915	4·5-in. and 4·7-in. shell; 60-pdr. and 6-in. shell heads; aero-engine cylinders.	Board of Management.	75,000
17. *Huddersfield*, Fitzwilliam Street ..	N.S.F.	June, 1915 (*c*)	Nov., 1915	18-pdr. shell and shell heads	Board of Management.	31,500
18. *Dublin*, Parkgate Street	N.S.F.	June, 1915 (*c*)	March, 1916	18-pdr. shell	Board of Management.	119,600[1]
19. *Liverpool*, Cunard Co., Rimrose Road	N.S.F.	June, 1915,(*c*)	—	8-in., 6-in. and 4·5-in. shell	Board of Management.	16,600
20. *Liverpool*, North Haymarket ..	N.S.F.	June, 1915 (*c*)	—	18-pdr., 4·5-in. and 6-in. shell ..	Board of Management.	131,000
21. *Liverpool*, Lambeth Road Tramway Depot.	N.S.F.	June, 1915 (*c*)	July, 1915	18-pdr. shell; completing and rectifying 18-pdr., 15-pdr. 2·75-in., 4·5-in. and 60-pdr.	Board of Management.	22,000
22. *Nottingham*, Spring Close Works, Old Lenton.	N.S.F.	June, 1915 (*c*)	Late 1915	13-pdr., 18-pdr. and 2·75-in. shell; completing 18-pdr.	Board of Management.	25,800
23. *Rotherham*, Brinsworth Iron Works and Rotherham Iron Works.	N.S.F.	June, 1915 (*c*)	Nov., 1915	4·5-in. shell	Board of Management.	53,000
24. *Dundee*, 51–63, Mains Road ..	N.S.F.	June, 1915 (*c*)	Sept., 1915	18-pdr. and 2·75-in. shell; forgings; burster containers.	Board of Management.	34,000
25. *Ebbw Vale* [Mon.][2]	N.S.F.	June, 1915 (*c*)	Aug., 1915	18-pdr. and 60-pdr. shell	Board of Management.	32,200
26. *Cardiff*, Ferry Road, Grangetown ..	N.S.F.	June, 1915 (*c*)	Late 1915	18-pdr. shell, 60-pdr. shell heads, 6-in. proof shot.	Board of Management.	28,500
27. *Swansea*, Messrs. Baldwin's Works, Landore.	N.S.F.	June, 1915 (*c*)	Late 1915	18-pdr. and 4·5-in. shell	Board of Management.	40,500
28. *Wrexham*, Corporation Electric Works	N.S.F.	July, 1915 (*c*)	Spring, 1916	Making and completing 18-pdr. and 13-pdr. shell.	Board of Management.	9,000
29. *Uskside*, Uskside National Works, Newport [Mon.]	N.S.F.	July, 1915 (*n*)	—[3]	18-pdr., 4·5-in. and 60-pdr. shell; proof shot and gun-carriage forgings, &c.	Board of Management.	61,900
30. *Gadbrook* [nr. Northwich, Cheshire]	H.M.E.F.	July, 1915 (*c*)	Feb., 1916	Purifying crude T.N.T.	Brunner Mond ..	195,000[4]

31. *Gretna* [nr. Carlisle]	H.M.E.F.	July, 1915 (*c*)	June, 1916	Cordite R..D.B.	Direct Control	9,295,000*
32. *Hackney Wick*, Wallis Rd. [London, N.E.]	H.M.E.F.	July, 1915 (*n*)	July, 1915	T.N.T.	Direct Control	66,200*
33. *Penrhyn Deudraeth* [N. Wales]	H.M.E.F.	July, 1915 (*n*)	Jan., 1916	T.N.T.	Direct Control	83,000*
34. *Liverpool*, Aintree	N.F.F.	July, 1915 (*c*)	June, 1916	Filling shell up to 8-in.; filling and assembling components.	Board of Management.	725,400
35. *Coventry*, Foleshill	N.F.F.	July, 1915 (*c*)	March, 1916	Filling fuses, gaines and other components.	White & Poppé	813,400
36. *Watford*	H.M.E.F.	Aug., 1915 (*c*)	Dec., 1915	Ammonal, amatol, smoke powder, &c.; experimental work.	Direct Control	106,800
37. *Barnsley* (*No.* 1), Dominion Works, Johnson Street.	N.S.F.	Aug., 1915 (*c*)	Jan., 1916	4·5-in. shell	Board of Management.	51,000
38. *Grimsby*, Victoria Street	N.S.F.	Aug., 1915 (*c*)	Dec., 1915	4·5-in. and 6-in. shell	Board of Management.	28,700
39. *Leeds*, Newlay[5]	N.S.F., N.P.F., N.O.F.	Aug., 1915 (*c*)	April, 1916	9·2-in. and 15-in. shell	Board of Management.	230,600
40. *Chester*, Tramway Depot	N.S.F.	Aug., 1915 (*c*)	—	18-pdr. and 2·75-in. shell	Board of Management.	2,400
41. *Birtley* [Co. Durham]	N.P.F.	Aug., 1915 (*c*)	July, 1916	4-in., 4·5-in., 60-pdr., 6-in., 8-in. shell; proof shot.	Belgian Government	892,800
42. *Dudley*, Waddam's Pool	N.P.F.	Aug., 1915 (*c*)	Early 1916	18-pdr., 60-pdr. and 6-in. shell; gun repair (1917), aero-engine work (1918)	Bean & Son	788,000
43. *Glasgow*, Mossend	N.P.F.	Aug., 1915 (*c*)	Late 1916	Shell forgings	Beardmore, Ltd.	1,107,600
44. *Glasgow*, Grant's Mill, Mile End[6]	N.P.F.	Aug., 1915 (*c*)	March, 1916	18-pdr., 60-pdr. and 6-in. shell	Beardmore, Ltd.	
45. *Glasgow*, Cardonald, Paisley[7]	N.P.F.	Aug., 1915 (*c*)	March, 1916	18-pdr., 6-in. and 8-in. shell; gun repair (1917).	Beardmore, Ltd.	
46. *Lancaster*	N.P.F.	Aug., 1915 (*c*)	March, 1916	60-pdr., 6-in., 8-in. and 9·2-in. shell; gun repair and trench warfare work (1917).	Vickers, Ltd.	1,580,200
47. *Nottingham*, King's Meadow Road[8]	N.P.F., N.O.F.	Aug., 1915 (*c*)	March, 1916	6-in. and 9·2-in. shell; making and repairing 18-pdr. guns (1917–18).	Cammell, Laird	796,500
48. *Chilwell*, Long Eaton [Notts.]	N.F.F.	Aug., 1915 (*c*)	Jan., 1916	Filling shell (4·5-in. to 15-in.)	Direct Control	2,712,100
49. *Perivale*, Willesden Lane [London, N.W.]	N.F.F.	Aug., 1915 (*c*)	Dec., 1915.	Filling shell components; experimental work.	(*a*) Metropolitan Munitions Committee (*b*) Direct Control	522,800
50. *Morecambe*, White Lund [Lancs.]	N.F.F.	Aug., 1915 (*c*)	Summer, 1916	Filling 60-pdr., 6-in., 8-in., 9·2-in. and 12-in. shell.	Vickers, Ltd.	199,900
51. *Southwark*, Sumner St. [London, S.E.].[9]	N.F.F.	Aug., 1915 (*c*)	Sept., 1915	Filling shell components; inspecting protective clothing (1918).	Direct Control	41,100
52. *Cathcart*, Holm Foundry [nr. Glasgow.][10]	N.P.F.	Sept., 1915 (*c*)	April, 1916	8-in. shell; aeronautical work (1917–18).	G. & J. Weir	36,100
53. *Sheffield*, Tinsley [nr. Sheffield] and Templeborough [nr. Rotherham.]	N.P.F.	Sept., 1915 (*c*)	Jan., 1916	Shell forgings; 4·5-in. and 60-pdr. shell.	T. Firth & Sons	661,800

[1] Includes expenditure on Dublin 9·2-in. and Fuse Factories (Nos. 93 & 105). [2] Closed down July, 1916. [3] Already in operation when taken over.
[4] Expenditure to July, 1918. [5] Classed as an N.P.F. 1916–17; N.O.F. 1917–18. [6] Also known as Bridgeton. [7] Also known as Craigton. [8] Classed as N.O.F. 1917–18.
[9] Transferred to Anti-Gas authorities in 1918; later used for storing the Ministry archives. [10] Transferred to Controller of Aeronautical Supplies May, 1917.

Name and Address of Factory.	Class of Factory.	Date of Initiation.	Date of First Output.	Output.	Form of Administration.	Capital Expenditure to 31/3/18.*
						£
54. *Sheffield*, East Hecla Works. ..	N.P.F., N.O.F. ..	Sept., 1915 (*c*)	March, 1916	9·2-in. shell; 60-pdr. guns and gun repairs (1917–18).	Hadfield Ltd. ..	487,800
55. *Bury*, Corporation Tramway Depot	N.S.F.	Sept., 1915 (*c*)	Summer, 1916	18-pdr. and 4·5-in. shell; rectifying shell.	Board of Management.	11,700
56. *Carlisle*, Drill Hall, Strand Rd. ..	N.S.F.	Sept., 1915 (*c*)	Early, 1916	18-pdr. shell; rectifying proof shot ..	Board of Management.	12,800
57. *Liverpool*, Edge Lane	N.S.F.	Sept., 1915 (*c*)	Feb., 1916	4·5-in. and 6-in. shell forgings; 4·5-in. cartridge cases.	Board of Management.	96,000
58. *Llanelly*, Burry Extension Works ..	N.S.F.	Sept., 1915 (*c*)	Feb., 1916	6·in. shell.	Board of Management.	171,500[1]
59. *Abbey Wood* [London, S.E.] ..	N.F.F.	Sept., 1915 (*c*)	Jan., 1916	Filling and assembling shell components.	King's Norton Metal Co.	116,400
60. *Gloucester*, Quedgeley	N.F.F.	Sept., 1915 (*c*)	March, 1916	Filling 18-pdr., 4·5 in. and 60-pdr. shell, cartridges and components.	Board of Management.	410,400
61. *Georgetown* [Paisley]..	N.F.F.	Sept., 1915 (*c*)	Jan., 1916	Filling shell (13-pdr. to 12-in.), cartridges, components, trench mortar bombs.	Board of Management.	1,368,400
62. *Hayes* [Middlesex]	N.F.F.	Sept., 1915 (*c*)	Oct., 1915	Filling shell (18-pdr. to 12-in.), cartridges, components.	Direct Control ..	899,000
63. *Leeds*, Barnbow[2]	N.F.F.	Sept., 1915 (*c*)	Dec., 1915	Filling shell (18-pdr. to 6-in.), cartridges, components.	Board of Management.	813,500
64. *Cardonald*, Govan [Glasgow] ..	N.F.F.	Sept., 1915 (*c*)	Jan., 1916	Filling minor shell components. ..	Nobel's Explosives Co.	63,500
65. *Watford* (*No.* 1), Balmoral Road ..	T.W.F.F.	Sept., 1915 (*c*)	Oct., 1915	Filling and assembling trench warfare bombs; filling chemical shell exploders.	Direct Control ..	40,306
66. *Birmingham*, Great Tindal Street	National Gauge Factory.	Sept., 1915 (*n*)	—[3]	Gauges, small tools, &c.	Chatwin, Ltd. ..	2,900*
67. *Renfrew*, Ypres Factory	N.P.F.	Sept., 1915 (*c*)	Summer, 1916	9·2-in. and 12-in. forgings and shell ..	Babcock & Wilcox	165,900
68. *Trafford Park* [Barton, Manchester]	H.M.E.F. ..	Oct., 1915 (*c*)	July, 1916	Refining toluol	Hardman & Holden	37,400*
69. *West Gorton* [Manchester] ..	H.M.E.F. ..	Oct., 1915 (*n*)	—[3]	Synthetic phenol and T.N.T.	Direct Control ..	304,400*
70. *College Park* [Willesden, N.W.][4] ..	N.S.F., N.P.F. ..	Oct., 1915 (*n*)	—[3]	Shell components	(*a*) Metropolitan Munition Committee; (*b*) Direct Control.	4,000
71. *Carnarvon*, Vulcan Factory.. ..	N.S.F.	Oct., 1915 (*c*)	—	13-pdr. and 18-pdr. shell	Board of Management.	2,800
72. *Rochdale*, Mellor Street	N.S.F.	Oct., 1915 (*c*)	July, 1916	6-in shell	Board of Management.	19,600

73. *Hackney Marshes* [London, N.E.] ..	N.P.F.	Oct., 1915 (*c*)	Feb., 1916	6·in. shell and proof shot	(*a*) Dick Kerr; (*b*) Direct Control	652,600
74. *Newport*, Maesglas and Tyne Engine Works.	N.S.F.	*c*Oct., 1915 (*c*)	June, 1916	60-pdr. shell; 4·5-in. and 9·2-in. nose bushes.	Board of Management.	112,400
75. *Portmadoc*, Boston Lodge Works ..	N.S.F.	*c*Oct., 1915 (*c*)	—	13-pdr. and 18-pdr. shell . ..	Board of Management.	3,700
76. *Langwith* [nr. Mansfield, Notts.] ..	H.M.E.F.	Nov., 1915 (*c*)	June, 1917	Ammonium perchlorate . ..	Direct Control ..	717,400*
77. *Croydon*, Gloucester Road	National Gauge Factory.	Nov., 1915 (*n*)	—[3]	Gauges	Vidal Engineering Co.	14,800*
78. *Workington*, Stanley Street ..	N.S.F.	Nov., 1915 (*c*)	Aug., 1916	18-pdr. shell; base plates	Board of Management.	12,700
79. *Renfrew*, Aisne Factory	N.P.F.	Nov., 1915 (*c*)	May, 1916	60-pdr. shell	Babcock & Wilcox	114,600
80. *Liverpool*, Clyde Street, Bootle ..	N.S.F.	Nov., 1915 (*c*)	—	Gauges	Board of Management.	6,300
81. *Hartlepool*, Central Marine Engine Works[5]	N.S.F.	Dec., 1915 (*c*)	Autumn, 1916	8-in. shell	Board of Management.	48,500
82. *Rawtenstall and Bacup*, Irwell Mill, Bacup.	N.S.F.	Dec., 1915 (*c*)	Summer, 1916	4·5-in. shell.	Board of Management.	7,400
83. *Banbury* [Oxon]	N.F.F.	Dec., 1915 (*c*)	April, 1916	Filling shell (6-pdr. to 9·2-in.), H.2 Mines (1917-18).	Direct Control ..	174,000
84. *Sutton Oak* [St. Helen's, Lancs.] ..	H.M.E.F.	Jan., 1916(*n*)	—[3]	Synthetic Phenol; chemicals (1918).	Direct Control ..	100,700
85. *Denaby* [nr. Rotherham]	T.W.F.F.	Jan., 1916 (*n*)	—[3]	Filling 3-in. Stokes bombs; disassembling 3·7-in. bombs (1917).	British Westfalite Co.	14,700
86. *Erith*, Crayfordness, Slades Green [Kent].	T.W.F.F.	Jan., 1916 (*n*)	—[3]	Filling 2-in. and 6-in. trench mortar bombs.	Direct Control ..	42,000
87. *Fulham*, Stevenage Road [London, S.W.]	T.W.F.F.	Feb., 1916(*n*)	—[3]	Filling grenades, Stokes bombs and components; pyrotechnic work, &c.	Direct Control ..	19,700
88. *Watford* (*No.* 2), Bushey Mill Lane..	T.W.F.F.	Feb., 1916 (*c*)	May, 1916	Filling bombs, grenades, &c., filling and assembling aerial bombs and trench mortar fuses; assembling chemical shell.	Direct Control	99,000
89. *Victoria* [Winsford, Northwich] ..	H.M.E.F.	Feb., 1916 (*c*)	Aug., 1916	Calcium nitrate tetrahydrate ..	(*a*) Salt Union (*b*) Direct Control.	608,300
90. *Ellesmere Port* [Cheshire]	H.M.E.F.	March, 1916(*c*)	May, 1917	Synthetic phenol: chemicals (1918)	Direct Control ..	160,800*
91. *Litherland* [Liverpool]	H.M.E.F. ..	March, 1916(*n*)	—[3]	T.N.T.	Direct Control ..	185,000*
92. *King's Lynn* [Norfolk]	H.M.E.F.	March, 1916(*n*)	—[3]	Acetone	Direct Control ..	4,300*
93. *Dublin*, Parkgate Street	N.S.F.	March, 1916(*c*)	April, 1917	9·2-in. shell	Board of Management.	—[6]
94. *Manchester*, Hyde Road	N.S.F.	March, 1916 (*c*)	Summer, 1916	4·5-in. shell	Board of Management.	16,500
95. *Leeds*, Hunslet[7]	N.S.F., N.P.F., N.O.F.	Early 1916 (*c*)	Aug., 1916	9·2-in. and 15-in. shell; making and repairing guns (1917–18).	Board of Management.	274,400
96. *Leeds*, Armley Road, Wellington Street, and Sweet Street.[7]	National Fuse Factory.	Early 1916 (*c*)	—	Shell components	Board of Management.	26,400

[1] Includes Llanelly Rectification Factory (No. 115). [2] Also known as Crossgates. [3] Already in operation when nationalised.
[4] Classed as an N.P.F. in 1918. [5] Transferred to Admiralty, December, 1917. [6] Expenditure included with Dublin 18-pdr. Shell Factory (No. 18).
[7] Classed as N.P.F. 1916–17; N.O.F. 1917–18.

Name and Address of Factory.	Class of Factory.	Date of Initiation.	Date of First Output.	Output.	Form of Administration.	Capital Expenditure to 31/3/18.*
						£
97. *Cork*, North Main Street	N.S.F.	Early 1916 (*c*)	Feb., 1917	4·5-in. shell	Board of Management	14,000
98. *Dagenham Dock* [Essex]	National Cartridge and Box Repair Factory.	Early 1916 (*c*)	Early 1916	Repairing cartridge cases and ammunition boxes.	Direct Control ..	124,300
99. *Southampton*, Woolston	Government Rolling Mills.	April, 1916 (*c*)	Feb., 1917	Brass and cupro-nickel strips and cups	Mr. G. H. Robinson	1,089,900
100. *Blackheath* [Staffs.]	G.C.F.	*c* April, 1916 (*c*)	Dec., 1916	Small arms ammunition	Birmingham Metal & Munitions Co.	392,000
101. *Blackpole* [Worcs.]	G.C.F.	*c* April, 1916 (*c*)	Early, 1917	Small arms ammunition	King's Norton Metal Co.	289,800
102. *Craigleith* [Edinburgh]	H.M.E.F.	April, 1916 (*c*)	Feb., 1917	T.N.T.	Lothian Chemical Co.	67,900*
103. *Gateshead*, Coulthard's Lane ..	National Tool Factory.	May, 1916 (*c*)	Aug., 1916	Spade-cutters	Direct Control ..	18,800
104. *Phœnix Factory* [Gray's Inn Road, London, W.C.]	National Fuse Rectification Factory.	May, 1916 (*n*)	—[1]	Rectifying and repairing fuses ..	William Cubitt, Ltd.	22,500
105. *Dublin*, Parkgate Street	National Fuse Factory.	May, 1916 (*c*)	March, 1917	Fuses; aeroplane bolts (1918) ..	Board of Management.	—[2]
106. *Selby*, Barlby Road [Yorks.] ..	T.W.F.F.	June, 1916 (*n*)	—	Hydrogen and hydrogenated oils; charging chemical shell.	Ardol, Ltd. ..	—
106.*a Colnbrook* [Mddx.]	H.M.E.F.	June, 1916 (*n*)	—[1]	Guncotton	Direct Control ..	—
107. *Walthamstow*, Black Horse Lane ..	T.W.F.F.	June, 1916 (*n*)	—[1]	Charging lachrymatory grenades, shells, &c.; head filling lethal shell.	(*a*) Baird & Tatlock (*b*) Direct Control.	9,900*
108. *Hereford*	N.F.F.	June, 1916 (*n*)	Nov., 1916	Filling shell (18-pdr. to 9·2-in.); charging gas shell (1918).	Direct Control ..	1,281,300
109. *Ailsa Craig* [Strand-on-Green, Chiswick.	N.S.F., N.P.F. ..	July, 1916 (*n*)	—[1]	4·5-in. shell	(*a*) Metropolitan Munitions Committee (*b*) Direct Control.	26,400
110. *Darlington*, N.E.R. Co.'s Works ..	N.P.F.	July, 1916 (*n*)	—[1]	18-pdr. and 6-in. shell; naval practice shot; repairing primers.	N.E.R. Co. ..	106,400
111. *Edmonton*, Angel Road[3]	G.C.F.	Aug., 1916 (*c*)	May, 1917	Small arms ammunition; aero-engine repair (1918).	Eley Bros. ..	284,200
112. *Greenford* [Middlesex]	Chemical Shell Assembling Station.	Aug., 1916 (*c*)	Jan., 1917	Assembling lethal shell	Direct Control ..	109,900
113. *Woolwich*, Upper Market Street ..	National Gauge Factory.	Aug., 1916 (*n*)	—[1]	Gauges	Pitter's Ventilating & Engineering Co.	34,500*
114. *Avonmouth* [Glos.][4]	H.M.E.F.	Sept., 1916 (*c*)	July, 1918	Mustard gas	Direct Control ..	1,578,200
115. *Llanelly*	N.S.F.	Sept., 1916 (*c*)	—	Rectifying 18-pdr. and 6-in. shell ..	Board of Management.	—[5]

116. *Luton*, Chaul End [Beds].	N.F.F.	Autumn, 1916(*c*)	Summer, 1917	Filling and converting fuses	George Kent, Ltd.	—
117. *Beddington* [Croydon]	Box Repair Factory	Nov., 1916 (*c*)	Early 1917	Repairing bomb and grenade boxes ..	Direct Control ..	7,200
118. *Waterford*	National Cartridge Factory. ..	Nov., 1916 (*c*)	Aug., 1917	Cartridge cases	Board of Management.	82,300
119. *Swindon*, Stratton Works	H.M.E.F.	Dec., 1916 (*c*)	Sept., 1917	Ammonium nitrate	Direct Control ..	927,600
120. *Galway*	N.S.F.	*c* Dec., 1916 (*c*)	Spring, 1917	18-pdr. shell	Board of Management.	4,000
121. *Trafford Park*, Manchester	Steel Billet Breaking Factory.	1916 (*c*)	—	Breaking steel billets to shell lengths..	Direct Control ..	142,200
122. *Woolwich*, Trinity Street	National Box Factory.	1916 (*c*)	Late 1916	Making and repairing ammunition boxes	W. Watt Torrance & Co.	3,200*
123. *Deptford* (*No.* 1), Pier Wharf [London, S.E.]	National Box Factory.	1916 (*c*)	Late 1916	Making and repairing tin boxes ..	Direct Control ..	5,400*
124. *Stamford Hill*, L.C.C. Stores Depot [London, N.]	Anti-Gas Factory	1916 (*c*)	Feb., 1917	Granules	Direct Control ..	—
125. *Willesden*, Park Royal [London, N.W.]	National Box Factory.	Jan., 1917 (*n*)	—	Making and repairing ammunition boxes	Direct Control ..	28,000*
126. *Pembrey* [Carmarthen]	H.M.E.F.	Jan., 1917 (*n*)	—[1]	T.N.T., tetryl, and propellants ..	Nobel's Explosives Co.	2,850,600*
127. *Pembrey*, Burry Port [Carmarthen]	N.F.F.	Jan., 1917 (*n*)	—[1]	Filling 4·5-in., 6-in., 8-in. shell; breaking down shell, &c. (1917–18).	Explosives Loading Co.	102,300
128. *Pimlico*, Gatliff Road [London, S.W.]	National Gauge Factory.	Jan., 1917 (*n*)	—[1]	Gauges	Wolseley Motor Co.	22,000
129. *Bradley* [Yorks.]	H.M.E.F.	Jan., 1917 (*c*)	—	Picric acid	Major L. B. Holliday	369,500*
130. *Greetland* [nr. Halifax]	H.M.E.F.	Jan., 1917 (*c*)	Aug., 1917	Picric acid	Sharp & Mallett ..	183,600*
131. *Lytham* [Lancs.]	H.M.E.F.	Jan., 1917 (*c*)	July, 1917	Picric acid	(*a*) Mr. Lance Blythe (*b*) Direct Control	166,800*
132. *Irvine* [Ayrshire]	H.M.E.F.	Jan., 1917 (*c*)	Feb., 1918	Nitrocellulose powder	Nobel's Explosives Co.	953,200*
133. *Cowley* [nr. Oxford]..	Mine Sinker Assembly Station.	March, 1917 (*n*)	Aug., 1917	Assembling naval mine sinkers ..	W.R.M. Motors, Ltd.	21,600
134. *Ponders End* [Middlesex]	N.P.F.	March, 1917 (*n*)	—[1]	6-in., 8-in., 12-in. shell; 6-pdr. guns; repairing guns.	Direct Control ..	812,200*
135. *Aberdeen*, Spring Garden Iron Works	N.S.F.	March, 1917 (*n*)	—[1]	Completing 6-in. shell	Board of Management.	600
136. *Longparish* [nr. Andover]	H.M.E.F.	Early 1917 (*n*)	—[1]	Producing acetate of lime by wood distillation.	Kynoch, Ltd. ..	86,800*
137. *Tipton* [Staffs.]	National Components Factory.	Early 1917 (*c*)	—	Gun ammunition components.. ..	Bean & Son ..	—
138. *Newport*, Alexandra Dock [Mon.] ..	National Cartridge & Box Repair Factory.	Early 1917 (*c*)	—	Repairing cartridge cases and ammunition boxes.	Direct Control ..	314,000
139. *Erith*, Cory's Wharf, Belvedere [Kent]	Non-returnable Box Depot.	*c* April, 1917 (*c*)	April, 1917	Repairing and converting non-returnable boxes.	Direct Control ..	—
140. *Willesden*, Park Royal [London, N.W.]	Non-returnable Box Depot.	*c* April, 1917 (*c*)	April, 1917	Repairing and converting non-returnable boxes.	Direct Control ..	2,20

[1] Already in operation when nationalised. [2] Expenditure included with Dublin 18-pdr. Shell Factory (No. 18). [3] Transferred to Air Board, early 1918.
[4] Original plans for picric acid production abandoned early 1918. [5] Expenditure included with Llanelly Shell Manufacture Factory (No. 58).

Name and Address of Factory.	Class of Factory.	Date of Initiation.	Date of First Output.	Output.	Form of Administration.	Capital Expenditure to 31/3/18*
						£
141. *Kilburn*, Fairfax Yard [London, N.W.]	National Gauge Factory.	May, 1917 (*c*)	—	Gauges	Direct Control ..	2,100*
142. *Rotherhithe*, Plough Road [London, S.E.]	National Sawmill..	July, 1917 (*n*)	—	Sawing timber	Priddy & Hale ..	11,500
143. *Glasgow*, 45, Milton Street, Partick..	National Sawmill..	July, 1917 (*n*)	—	Sawing timber	A. McDougall's Timber Co.	9,400
144. *Coundon* [nr. Coventry]	National S.A.A. Factory.	July, 1917 (*c*)	Sept., 1917	Special small arms ammunition ..	Direct Control ..	12,600*
145. *Bucknall*, Hanley [Staffs.]	Cylinder Depot ..	July, 1917 (*n*)	—[1]	Evacuating and refilling cylinders with chemicals.	Direct Control ..	11,500*
146. *Bury*, Calrow Mill	H.M. Cotton Waste Mills.	Aug., 1917 (*n*)	—[1]	Cotton waste	(*a*) British & Foreign Supply Association; (*b*) Direct Control.	455,400*
147. *Charlesworth*, Lee Valley Mill ..						
148. *Greenfield* [Yorks.]						
149. *Hadfield*, Waterside Mill						
150. *Oldham*						
151. *Rawtenstall*, Cloughfold, Constablelee & Holme Mills.						
152. *Whaley Bridge*, Hall's Mill						
153. *Woodley*, Arden Mill						
154. *Glasgow*, Whiteinch	National Sawmill	Sept., 1917 (*n*)	—	Sawing timber	J. Smellie & Co. ..	—
155. *Kilmarnock*, Bonington Road ..	National Sawmill..	Sept., 1917 (*n*)	—	Sawing timber	Brownlie & Co. ..	1,300
156. *Chelmsford* [Essex]	National Ball Bearing Factory.	Sept., 1917 (*n*)	—[1]	Ball bearings	Hoffman Manufacturing Co.	—
157. *Waddon* [Croydon]	N.A.F.	Sept., 1917 (*c*)	March, 1918	Aeroplanes and C.C. interrupter gears	Holland & Hannen & Cubitt.	778,300*
158. *Castleford* [Leeds]	National Box Factory.	Autumn 1917	by Oct., 1917	Making and repairing ammunition boxes.	Direct Control ..	2,500*
159. *Leeds* [Wellington Street]	National Box Factory.	Autumn 1917	by Oct., 1917	Making and repairing ammunition boxes.	J. H. Abrahams, Ltd.	2,300*
160. *Letchworth*	National Box Factory.	Autumn 1917	by Oct., 1917	Making and repairing ammunition boxes.	Co-partnership Co.	2,800*
161. *Liverpool*, Brasenose Road, Bootle	National Box Factory.	Autumn 1917	by Oct., 1917	Making and repairing ammunition boxes.	Direct Control ..	3,000*
162. *Paisley*, Caledonia Sawmills ..	National Box Factory.	Autumn 1917	by Oct., 1917	Making and repairing ammunition boxes.	Direct Control ..	1,700*
163. *Burton-on-Trent*	Machine-Gun Factory.	Oct., 1917 (*c*)	Jan., 1919	Repairing machine guns	Direct Control ..	892,400*
164. *Aintree* [Liverpool]	N.A.F.	Oct., 1917 (*c*)	June, 1918	Aeroplanes	(*a*) Cunard Ltd. (*b*) Direct Control.	692,900*

165. *Heaton Chapel* [Manchester] ..	N.A.F.	Oct., 1917 (*c*)	April, 1918	Aeroplanes	Crossley, Ltd. ..	544,500*
166. *Hayes* [Middlesex]	Aero-Engine Factory.	Oct., 1917 (*n*)	—[1]	Aero-engine parts	(*a*) Mitchell Shaw (*b*) Direct Control	211,346
167. *Inverness*, The Sawmills	National Sawmill	Oct., 1917 (*n*)	—	Sawing timber	J. Walker & Co.	2,500
168. *Elgin*, Morayshire Sawmills ..	National Sawmill	Oct., 1917 (*n*)	—	Sawing timber	A. Watson & Co.	6,400*
169. *Barnsley* (*No.* 2), Hope Works, Sackville Street.	N.S.F.	Oct., 1917 (*c*)	—	4·5-in. shell	Board of Management.	14,500
170. *Keighley* (*No.* 2), Dalton Lane ..	N.S.F.	Oct., 1917 (*c*)	by Sept., 1918	18-pdr. shell castings	Board of Management.	—
171. *Southampton*, Northam	National Sawmill	Nov., 1917 (*n*)	—	Sawing timber	Driver & Co. ..	6,200
172. *Poole*, Hamworthy [Dorset] ..	National Sawmill	Nov., 1917 (*n*)	—	Sawing timber	J. T. Sydenham & Co.	4,600
173. *Gloucester*, Bristol Road	National Sawmill	Nov., 1917 (*n*)	—	Sawing timber	J. Griggs & Co. ..	7,300
174. *Dumfries*, Leafield	National Sawmill	Nov., 1917 (*n*)	—	Sawing timber	—	—
175. *Warrington*, Walton Lay Bye ..	National Sawmill	Nov., 1917 (*n*)	—	Sawing timber	R. A. Naylor, Ltd.	12,000*
176. *Luton*, Dunstable Road	National Sawmill	Nov., 1917 (*n*)	—	Sawing timber	H. Brown & Sons	7,000
177. *Chittening*	N.F.F.	Nov., 1917 (*c*)	June, 1918	Charging and assembling 6-in. chemical shell.	(*a*) Nobel's Explosives Co. (*b*) Direct Control.	57,900*
178. *Gainsborough*	N.F.F.	Nov., 1917 (*c*)	Feb., 1918	Filling mine sinkers	Direct Control ..	52,000
179. *New Basford* [Nottingham] ..	N.O.F.	Dec., 1917 (*c*)	May, 1918	1½-pdr. automatic gun	Coventry Ordnance Works	199,000*
180. *Rawtenstall and Bacup*, Height Barn Mill, Bacup.	N.S.F.	Late 1917 (*c*)	Early 1918	Rectifying 18-pdr. and 4·5-in. shell and 6-in. shell forgings.	Board of Management.	19,500
181. *Blyth* [Northumberland]	Salvage Depot ..	Late 1917 (*c*)	—	Storing and sorting salvage	Direct Control ..	5,900*
182. *Immingham* [Yorks]	Salvage Depot ..	Late 1917 (*c*)	—	Storing and sorting salvage	Direct Control ..	3,800*
183. *Manchester*, Trafford Park	Salvage Depot ..	Late 1917 (*c*)	—	Storing and sorting salvage from overseas.	Direct Control ..	9,200*
184. *Renfrew*	Salvage Depot ..	Late 1917 (*c*)	—	Storing and sorting salvage	Direct Control ..	5,500*
185. *Ridham* [Kent]	Salvage Depot ..	Late 1917 (*c*)	—	Storing and sorting salvage	Direct Control ..	64,200*
186. *Westminster*, 14, Palmer Street ..	Small Tools Factory.	1917 (*n*)	—	Small tools	Coats Machine Tool Co.	8,300
187. *Glasgow*, Salamanca Street, Parkhead.	National Box Factory.	1917	—	Making and repairing tin boxes ..	Direct Control ..	—
188. *Deptford* (*No.* 2), Kent Wharf [London, S.E.].	National Box Factory.	1917–18	—	Making and repairing tin boxes ..	Direct Control ..	—
189. *Sheffield*, 50, Porter Street	Manufacturing Warehouse	1917–18	—	Cupro-nickel strip ; brass discs ..	Direct Control ..	731*
190. *Merthyr Tydfil*, Cyfarthfa	Rolling Mills & Blast Furnaces.	1917–18	—	Basic pig iron ; rolling 18-pdr. shell steel bars.	Crawshay Bros. ..	78,300
191. *Swindon*, G.W.R. Co.'s Works ..	Timber Drying Kiln	1917–18	July, 1918	Drying timber for aircraft	G.W.R. Co. ..	6,500
192. *Lancing*, L.B. & S.C.R. Co.'s Works	Timber Drying Kiln	1917–18	July, 1918	Drying timber for aircraft	L.B. & S.C.R. Co.	6,500
193. *Ladbroke Grove*, Barlby Road [London, W.].	Aero-Engine Factory.	Jan., 1918 (*n*)	—	Repairing aero-engines	Clement Talbot ..	141,700*

[1] Already in operation when nationalised.

Name and Address of Factory.	Class of Factory.	Date of Initiation.	Date of First Output.	Output.	Form of Administration.	Capital Expenditure to 31/3/18*
194. *Finchley*, Church End [London, N].	Balloon Factory ..	Jan., 1918 (*c*)	April, 1918	Balloons	(*a*) Sidney Davidson Balloon Co. & Davidson Aviation Co. (*b*) Direct Control.	£ 16,500*
195. *Greet* [Birmingham]	Radiator Factory	Jan., 1918 (*n*)	—[1]	Radiators for aeroplanes ..	Motor Radiator Manufacturing Co.	64,600
196. *Sudbury* [Suffolk]	Radiator Factory	Jan., 1918 (*n*)	—[1]	Radiators for aeroplanes ..		
197. *Berwick-on-Tweed*, Tweed Sawmills	National Sawmill	Feb., 1918 (*n*)	—	Sawing timber	Allan Bros. ..	5,900
198. *Kentish Town*, 23, Prince of Wales Crescent.	Optical Munitions Factory.	Feb., 1918 (*n*)	—[1]	Optical instruments	Control through Board of Directors.	80,000
199. *Southampton*, Empress Road ..	Gun Carriage Repair Factory.	Early 1918 (*c*)	Early 1918	Repairing gun carriages and breech mechanisms.	Direct Control ..	18,600*
200. *Mid-Lavant* [nr. Chichester][2] ..	H.M.E.F.	Spring 1918 (*c*)	—	Intended to produce acetate of lime .	Direct Control ..	86,700*
201. *Ludlow* [Shropshire][2]	H.M.E.F.	Spring 1918 (*c*)	—	Intended to produce acetate of lime ..	Direct Control ..	60,700*
202. *Walthamstow*, Black Horse Lane ..	National Gauge Factory	Spring 1918 (*n*)	—[1]	Gauges	Direct Control ..	5,500*
203. *Langley*	Chemical Warfare Factory.	Spring 1918 (*c*)	Sept., 1918	Chemicals	Agency ..	117,300
204. *Maidstone*	National Box Factory.	1918	—	Making and repairing tin boxes ..	Direct Control ..	—
205. *Luton*	National Box Factory	1918	—	Making and repairing tin boxes ..	Direct Control ..	—
206. *Guildford*, Walnut Tree Close ..	National Box Factory.	1918	—	Making and repairing tin boxes ..	Direct Control ..	6,000*
207. *Paisley* (*No.* 2), McKean Street ..	National Box Factory.	1918	—	Making and repairing tin boxes ..	Direct Control ..	4,400*
208. *Sheffield*, Bacon Lane	Casting Shop ..	April, 1918	—[1]	Bullets	Direct Control ..	1,200
209. *Birmingham* (*No.* 1), Lench Street[3]	National Rifle Factory.	May, 1918 (*n*)	—	Intended to make and assemble parts of Farquhar-Hill rifle	Standard Small Arms Co.	166,500*
210. *Birmingham* (*No.* 2), Garrison Lane[3]	National Rifle Factory.	May, 1918 (*n*)	—	Intended to make barrels of Farquhar-Hill rifle.	Standard Small Arms Co.	

211. *Gotham* [Notts.]	Concrete Slab Factory.	1918 (*c*)	—	Plaster slabs	King & Co. ..	16,600
212. *Yate* [Glos].	Concrete Slab Factory.	1918 (*c*)	June, 1918	Concrete slabs	R. McAlpine & Sons.	39,700
213. *Sandycroft* [nr. Chester]	H.M.E.F.	June, 1918 (*n*)	—[1]	M.N.T.	Direct Control ..	616,000*
214. *Brimsdown*, Green Street [Enfield, London, N.]	Photographic Lens Factory.	1918 (*c*)	July, 1918	Photographic lenses	Direct Control ..	6,000*
215. *Middlewich*	Chemical Warfare Factory.	Aug., 1918 (*n*)	—[1]	Making and charging poison gas ..	Direct Control ..	—
216. *Rainham*	Chemical Warfare Factory.	1918 (*n*)	—	Chemicals	Direct Control ..	40,200
217. *Holloway*, Batavia Mills [London, N.]	Anti-Gas Factory	Aug., 1918 (*c*)	Aug., 1918	Respirators	Direct Control ..	—
218. *Holloway*, Holloway Mills [London, N.]	Anti-Gas Factory	Aug., 1918 (*c*)	Aug., 1918	Respirators	Direct Control ..	—

[1] Already in operation when nationalised. [2] The factory did not reach the production stage. [3] Abandoned in October, 1918, before output was reached.

INDEX OF NAMES OF FACTORIES.

Key to Abbreviations.

H.M.E.F. = H.M. Explosives Factory.
N.S.F. = National Shell Factory.
N.P.F. = National Projectile Factory.
N.O.F. = National Ordnance Factory.
N.F.F. = National Filling Factory.
T.W.F.F. = Trench Warfare Filling Factory.
G.C.F. = Government Cartridge Factory.
N.A.F. = National Aircraft Factory.

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HISTORY OF THE MINISTRY OF MUNITIONS

VOLUME VIII

THE CONTROL OF INDUSTRIAL CAPACITY AND EQUIPMENT

PART III

ENGINEERING SUPPLIES

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THE CONTROL OF INDUSTRIAL CAPACITY AND EQUIPMENT

PART III

ENGINEERING SUPPLIES

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CHAPTER I.

GAUGES.

I. The Use of Gauges.

It will be convenient to preface this section with a summary account of the use of gauges in modern manufacture, for though the principles involved are so familiar as to need no explanation, the precise application of them is not so well known. It is only within the last 30 years that limit gauges have been employed in large scale production by even the most progressive firms and institutions; at the outbreak of war they were practically unknown, except in their simplest and most rudimentary forms, throughout large parts of the engineering industry of this country.

(*a*) Interchangeable Parts.

Whenever a mechanism consists of several distinct parts it is necessary that these parts should fit each other properly. The simplest and most rudimentary way of securing the necessary fit is to hand over the entire manufacture of the mechanism to a single skilled craftsman, who will adjust the dimensions of each part by trial and error to suit those of the other parts into which it has to fit. This method is still employed in the manufacture of articles which are made in small quantities only, and in which the replacement of damaged parts is not likely to be necessary. The need for more advanced methods arose first in the making of such objects as bicycles, the parts of which are liable to separate damage, while it is inconvenient to return the whole to the maker to have the damaged part replaced. When there is likely to be a demand for spare parts it is clearly an advantage to make all the separate parts of the mechanism in such a manner that any specimen of a part of one kind will always fit adequately any specimen of the part of the corresponding kind with which it has to act in conjunction. Parts of mechanisms constructed in this manner are said to be "standardised."

But the advantage of standardised parts is not confined to mechanisms in which there will be a need for spare parts. It is found that great economies in manufacture can be attained by a specialisation which permits the substitution of machine tools for hand tools and of relatively unskilled for relatively skilled labour. In modern practice the parts of any mechanism that has to be made in large quantities are not all produced by the same craftsmen, constantly varying the operation which they perform, but by machine tools, each of which makes one part only (or even performs only a single operation in the

making of one part) under the supervision of an operative who may understand that tool and no other. Thus the time fuse of a shell consists of some 30 metal parts ; all these parts are made independently, not necessarily in the same factory, and are never brought into the neighbourhood of each other until the fuse is finally assembled ; but when they are brought together they have to fit.

(*b*) Limit Gauges.

There are two obvious methods by which this object might be secured. One way would be to tell the workman in inches the desired dimensions of the part he has to make, and to give him some means of measuring inches. The other would be to provide him with a part similar in all respects to that into which his part has to fit ; the part so provided would then be a " gauge " in all essentials. The method adopted resembles the second rather than the first. It differs from the second in two respects which are best illustrated by a simple example. Suppose the part to be made is a cylindrical rod which, in the completed mechanism, has to fit snugly into a hole bored in a block with its end lying flush with the surface of the block. Then the fit will be determined by two dimensions of the rod, its diameter and its length. Instead of giving the workman as a gauge a hole in the block which will gauge both these dimensions, we shall probably give him two gauges, each to gauge one dimension. One of these gauges will be a hole in a plate which will enable him to judge whether the diameter of the rod is right, independently of its length, the other will be some kind of parallel jawed calipers which will enable him to judge whether the length is right, independently of the diameter. The other difference arises from a more accurate definition of what is meant by " fit." If the hole in the block is 0·500 inches in diameter and 2·00 inches long, the rod will fit the hole exactly only if it also has these dimensions. But the complete mechanism will probably work quite well if the fit is not exact, and if the diameter of the rod is slightly less than 0·500 in., and the length slightly less or slightly greater than 2·00 in. The extent to which the dimensions of the rod may differ from those of the hole, without spoiling the fit for practical purposes, will depend entirely on the purpose of the structure. The permissible difference is called the " tolerance," and is negative when the part may be slightly smaller than the ideal dimension, positive when it may be slightly larger. For the sake of illustration, the tolerance on diameter in the example may be supposed to be —·01 in., and that on length +·03 in. or —·03 in. That statement means that the diameter of the rod may be anything between 0·500 in. and 0·490 in., the length anything between 2·03 in. and 1·97 in.

Accordingly the workman can be enabled to judge whether his work lies within the permissible limits without having to judge exactness of fit by providing him with two gauges for each dimension instead of one, the two gauges representing the extremes of the tolerance. Thus, in place of a single ring gauge for diameter he will be given two, in one of which the diameter of the ring is 0·500 in., in the other 0·490 in. ; if the rod will go into the first gauge and not into the second, then its

diameter must lie within the prescribed limits and will fit satisfactorily so far as diameter is concerned. For length, again, two caliper gauges will be given, one having a dimension of 2·03 in., the other 1·97 in.; the length of rod will be satisfactory if it will go into the first and no into the second. Instead of attempting to make his rod fit exactly into a single gauge, the workman need only reduce its length and diameter until it will go into the larger pair of gauges; a single test will then show if it will go into the smaller pair; if it fails to go, then the rod is satisfactory. Anyone who has any familiarity with handicraft will realise that this use of a pair of gauges increases greatly the ease and speed of production.

Herein lies the fundamental principle of limit gauges. Its characteristic features are, first, that separate gauges are used to fix different dimensions; second, that two gauges are used to fix each dimension differing in size by a definite amount. These two gauges are termed respectively the "go" and the "not go" gauges. In the example we have taken, the "go" gauge is larger than the "not go," but it will be seen readily that if we had been concerned with the diameter of the hole instead of that of the rod the gauge would have been a rod and the "go" gauge would have been smaller than the "not go." The applications of the principle are exceedingly numerous and vary greatly with the nature of the dimension to be gauged; in some of them one or other of the characteristic features may seem to be abandoned, but closer examination will reveal it. Both features tend to make the number of gauges required for any mechanism greater than the number of its parts. Since most parts are characterised by more than one dimension and each dimension generally requires two gauges, the number of gauges will almost always be more than double the number of parts. Thus the time fuse already mentioned, which has 30 parts to be gauged, requires 160 gauges for its construction. It will be readily understood, therefore, that the application of limit gauges is useful only when large numbers of objects are all to be made with the use of the same gauges.

There is no need here to mention many of the practical problems which arise in connection with the use of such gauges. But it will be well to note that the statements made about the dimensions of the gauges are not strictly accurate. It is difficult and laborious to make gauges, as to make any other objects, precisely to prescribed dimensions; and even if they were so made, they would soon wear and become inaccurate. Accordingly, gauges are usually made with their limits somewhat inside those determined by the tolerances, and some tolerance is allowed on the dimensions of the gauge. It will be seen that so long as the dimensions of the two gauges fall somewhere within the prescribed limits, and so long as the gauge which should be the larger is actually the larger, it will be possible to produce work which will lie within the prescribed tolerance; the only penalty of making the difference between the gauges less than the full amount allowed by the tolerance is that the limits within which the work must lie to pass the gauges are reduced and with them the speed of production. In the choice of the dimensions of the gauges a compromise

has to be made between, on the one hand, ease of making the gauge and allowance for wear and, on the other, ease of producing work which will pass the gauge. In the example taken of a ring gauge for the diameter of the rod, a tolerance of ·001 in. might be allowed on the gauges, the extreme limits of which might be ·002 inside the tolerance allowed on the work. Thus the " go " gauge would have to lie between 0·498 and 0·497, the " not go " between 0·492 and 0·493.

(*c*) Inspection Gauges.

The gauges which have been considered so far are those supplied to the workman and are called " shop gauges." If shop gauges were always accurate and always used conscientiously, the work produced could be relied upon to be accurate and no inspection of the finished products would be required. But since these conditions are not fulfilled, inspection is necessary to see that the dimensions of the parts actually lie within the limits of the tolerances prescribed by the designer. Again, if gauges were made and could be kept exactly at the dimensions imposed by the tolerances there would be no necessary distinction between an inspection and a shop gauge ; any shop gauge which was known to be accurate might be used for inspection.

But, as was stated just now, the dimensions of shop gauges usually lie well within the permitted limits ; if such gauges were used for inspection they would reject work which did not exceed the prescribed tolerance. Thus, in the example the gauges would exclude rods of diameter 0·499 or 0·491 in., although such rods lie within the limits allowed by the designer. If all work is to be passed which falls within those limits no inspection gauge must have dimensions within those limits ; no " go " inspection gauge in our example must have a diameter less than 0·500 and no " not go " gauge a diameter less than 0·490. On the other hand, if the inspection gauge has dimensions outside the limits, it will pass work which may possibly not fit into the finished mechanism ; if an inspection gauge has a diameter as large as 0·501 it may pass rods which will not fit into a hole 0·500 in diameter. Ideally, therefore, an inspection gauge ought to be perfectly accurate ; and since this is practically impossible a choice has to be made between the chance of passing unsatisfactory work and that of giving a manufacturer a legitimate grievance. The former alternative is regarded as the less serious, and inspection gauges are allowed small tolerances outside the tolerance allowed on the work. Thus the inspection " go " gauge for the rod may be prescribed the limits 0·5005 and 0·5000 in., the " not go " 0·4900 and 0·4985. This alternative is selected because the chance of resulting error is so exceedingly small. It must be remembered that the hole into which the rod fits will be gauged as well as the rod ; and that the reasons which lead the manufacturer to make his rods all slightly smaller than 0·500 in. will lead him to make all his holes slightly greater than 0·500. Accordingly, in order that a rod and a hole, each passed by inspection gauges, should fail to fit, three separate and very small chances must concur ; the gauges used by the makers of the rod and hole must both exceed their intended limits, the rod and the hole must both lie at the very limit which the shop gauges will

pass, and the exceptional rod must meet the exceptional hole in the process of assembling. Such remote risks cannot cause any serious trouble.

But it is important to realise that inspection and shop gauges are not interchangeable. The use of inspection gauges as shop gauges is impossible, not merely because the former are often somewhat more accurate and, therefore, more expensive to make (for when the tolerances on the work are relatively large there is usually no difference in the tolerances allowed on inspection and shop gauges), but because work made by inspection gauges would often fail to pass other inspection gauges. The dimensions of shop gauges always lie, or should lie, within the limits imposed by the designer's tolerances; the dimensions of inspection gauges always lie rather outside those limits.

(*d*) GAUGES AND DESIGN.

The tolerance allowed by the designer on any part of the work, or, more accurately, the tolerances allowed on a pair of fitting parts, varies enormously with the function of those parts. On the length of a large shell a tolerance as great as $\frac{1}{2}$ in. may be allowed. To prescribe so large a tolerance may seem absurd, because there would be no difficulty whatever in making the length accurate within much closer limits; but here a large tolerance on length is allowed because there is only a very small tolerance on the weight of the shell, and the manufacturer can adjust the weight by altering the length. At the other extreme, the steel spheres made for ball-bearings are produced on the commercial scale with tolerances less than one ten-thousandth of an inch, which is probably the limit possible in large scale manufacture. The smallest tolerance allowed on any part of a shell or fuse is one thousandth of an inch, which is allowed on the diameter (0·078 in.) of the shearing wire of a percussion fuse. Here the necessity for accuracy arises not from a necessity for fit, but because the wire must shear when the strain on it reaches a certain figure. In certain parts of rifles, tolerances somewhat less than a thousandth of an inch are prescribed owing to the need for accurate fit.

A designer will always try to design his mechanism so that the tolerances may be as large as possible; for, of course, large tolerances mean quick and cheap manufacture. But it is gradually being realised that he must also consider questions of gauging. For, when the dimension to be gauged is part of a complicated structure, there may be considerable difficulty in finding a form of gauge which can be brought into the desired position. Thus a simple form of gauge which would be quite suitable for gauging the thickness of a flat plate could not be used to gauge the thickness of the wall of a nearly closed shell case; a much more complicated form would have to be introduced. It is sometimes possible by a slight change in the design of a part to render much easier the design of a gauge for it; and skilful designers and draughtsmen always bear in mind the necessity for gauging in making their designs. Many cases have occurred in the history of munitions manufacture in which slight changes of design have been introduced to facilitate gauging; and sometimes a choice has had to

be made between a form which is easy to manufacture but hard to gauge and one that is easy to gauge and hard to manufacture. Lack of foresight in this direction has only too often been a source of delay in production.

(*e*) Check Gauges.

By the use of limit gauges the workman is freed from the necessity of measuring his work in inches or comparing it with the primary standards of length. But such measurement and comparison must be undertaken at some stage of the process ; it is merely transferred to those who make and certify the gauges. The gauges must be measured in the course of manufacture to ascertain when the correct dimensions have been attained ; in practice they are always tested by some central standardising laboratory after they are made in order to avoid errors arising from carelessness or from imperfection of the standards with which they are compared.

Inspection and shop gauges are sometimes tested by a further application of the principle of limit gauges. When this method is adopted the testing gauges are known as " check gauges." For each dimension of the work which is to be gauged four check gauges are required, namely, a " go " and a " not go " check gauge for the " go " inspection or shop gauge, and a " go " and a " not go " gauge for the " not go " inspection or shop gauge. The check gauges must themselves be allowed some small tolerance, and the presence of this tolerance (like that allowed on inspection gauges) will again increase slightly the chance that work will be passed which will not fit into the mechanism ; but check gauges are made with very great care, and the tolerance on them is so small that the additional chance of error introduced by their use is inappreciable. Nevertheless check gauges are used in connection with only a small proportion of all the gauges to be tested, because, for reasons already stated, they are economical of time, labour, and expense only when very large numbers of precisely similar gauges have to be tested. In shell and fuse manufacture some 9,000 different types of gauges were required ; only about 20 per cent. of these were required in quantities so large that it was possible or desirable to make check gauges to test them.

When check gauges are not employed, the shop and inspection gauges have to be measured directly in terms of the standards of length. The standards employed for this purpose are almost always those made in Sweden by Johansson. These are plates or rods with surfaces or ends perfectly flat and parallel, so that standards of various lengths can be made up by simply placing two or more of the standards with their faces or ends in contact. The lengths of the various standards are so chosen that by suitable combinations of them a series of standards can be built up of any length between 0·2 in. and 8 in. (or more), each member of the series differing from the next member by 0·0001 in.[1] If

[1] The severe demand for these Johansson gauges experienced during the war led to several English firms undertaking the manufacture of similar plates, in which a considerable measure of success was obtained.

the gauge to be tested is one for measuring the length of a rod or the thickness of a plate all that is necessary is to find a combination of the Johansson plates which will just fit the gauge; the dimension of the gauge is then known from that of the combination which fits it. Modifications of this method are necessary when other forms of gauge are examined. For instance, if the internal diameter of a ring gauge is required two cylindrical rods are placed in the ring together with the Johansson plate, which will just fit between them. The diameter of the gauge is then the sum of the diameters of the cylindrical rods and the thickness of the plate. These diameters are found in turn by adjusting calipers so that the rods just fit into them and then finding a combination of Johansson plates, which will just fit into the same calipers. The principle involved is the exact opposite of that of limit gauges; in place of having separate gauges for each dimension, ingenuity is directed to using the same gauges to measure every different kind of dimension.

The tolerances allowed on gauges are, of course, as various as those allowed on the work, for it is only necessary that the former should be small compared with the latter. It is comparatively easy to make a gauge with a tolerance of ·001 in., and, except for the roughest work, larger tolerances are not prescribed. But when the tolerance on the work is only ·001, the tolerance on the shop gauge must be reduced to ·0002 or ·0003. When such small tolerances are allowed on the shop gauges, the tolerances on the inspection gauges will probably be no smaller; but when tolerances as great as ·001 are allowed on the shop gauge, only ·0005 may be permitted on the inspection gauge. The tolerances on check gauges have again to be small compared with those on the gauges which they have to check; in the example given they would probably not exceed ·0001 in. Lastly, the tolerances on the standards of length which are used for ultimate reference are always the smallest which are practically possible, and may be estimated at ·00001 in. It is possible to compare two standards of length to a much greater accuracy; with the greatest possible refinements applied to the most suitable standards differences of a few ten-millionths of an inch may be detected; but, of course, it is not possible to make a standard to a given length with the same accuracy as can be obtained in measuring that length.

(*f*) The Gauging of Screw Threads.

Among the parts of mechanisms which have to fit accurately are screw threads. The application of the principle of limit gauges to such threads presents considerable difficulties. Hitherto we have been dealing with parts characterised by a small number of dimensions, which can be gauged separately and are such that the parts will not fit unless all the dimensions lie within the prescribed limits. A screw thread, on the other hand, is characterised by many dimensions, some of which are not easy to gauge, and which are such that an error in one dimension may compensate for an error in another. Thus, two of the most important dimensions of a screw-thread on a plug are the

diameter[1] and the pitch. If the diameter is correct, then the plug will not fit the nut unless the pitch is correct within certain limits, and *vice versa*; on the other hand, an error in pitch which would prevent the plug fitting if the diameter were correct will not prevent it fitting if the diameter is somewhat too small. Accordingly, if we attempted to assign definite tolerances to each of the dimensions, we should meet with a dilemma. If we assigned such small tolerances that the screw would fit even if all the dimensions were at the limits of the tolerances and all the errors worked in the same direction, we should exclude screws some of which would fit adequately because the errors, though outside the tolerances, did not work in the same direction. While, if we assign any larger tolerances, there will be a danger of passing imperfect screws if all the errors should happen to work in the same direction. And even if tolerances could be assigned definitely, each of the dimensions would have to be gauged separately. Since there are no less than seven dimensions which determine the fit of a screw, and some of them are by no means easy to gauge, the labour involved in separate gauging would be prohibitive.

However, it is fortunately found that in practice complete gauging is not required. For most purposes a pair of gauges, one " go " and one " not go," suffice to reject imperfect work. For a screwed plug the " go " gauge is a threaded ring with a screw of perfect form made to the larger limit of the tolerances; it will reject any screw which is too large. The " not go " gauge, which rejects plugs that are too small, is a plain cylindrical ring, which gauges only the full diameter of the plug. It is possible that a screw plug may pass both these gauges and yet have threads which are undesirably thin; consequently in some important parts (*e.g.* the screw which fixes the fuse in the shell) a second " not go " gauge is employed which bears only on the flanks of the thread and through which the threads will slip if they are too thin.

By this method it is found possible to provide gauges which in practice suffice to reject all unsatisfactory work, although a screw could be produced by deliberate intention which would pass the tests and yet fail to fit its nut satisfactorily. But in the making and testing of the gauges themselves much more elaborate methods have to be adopted. The methods of testing screw gauges which were in use before the war were very crude and generally quite inadequate; they either were insufficiently searching or required elaborate work by a skilled observer, which is quite impossible when large numbers of gauges have to be examined. The development of more satisfactory methods of testing screw gauges has been one of the most fruitful contributions of scientific work to the increasing of the production of munitions.

If it were merely required to reject unsatisfactory gauges a system of check gauges might be devised similar to, but rather more elaborate than, that used for testing the finished work. But it is desirable to inform the manufacturer not merely that his gauge is incorrect but in

[1] A screw-thread is characterised by three different diameters (*see* page 9); the statement in the next sentence is strictly true only if diameter here means effective diameter.

what feature it is incorrect, and for this purpose it is desirable to measure the essential dimensions separately. Machines suitable for workshop use have been devised for measuring the pitch of the screw, its full diameter, its core diameter (or the diameter between the bottoms of the threads) and its effective diameter (which is roughly the diameter of a section perpendicular to the axis of the screw); but in addition to these the shape of the thread is of importance and is difficult to measure mechanically. A convenient and accurate method of testing this shape was developed which depends on the comparison of the thread with a standard thread by optical projection. By suitable optical methods, essentially similar to those employed in the projection lantern of the kinematograph, a shadow of the screw can be thrown on a screen, in which all the dimensions are enlarged in the same ratio. This ratio is about 50, and is so great that any divergence between the shadow of the actual thread and that of an ideal thread in its immediate neighbourhood can be detected at once by the eye and measured by a simple scale. Such procedure is only directly applicable to screw threads on plugs where the thread is raised above the plug. In order that it might be applied to the sunken threads of nuts, casts of the thread were taken in plaster of Paris; the raised thread thus produced could then be examined by projection. Even when the greatest care is taken there is some loss of accuracy in making the cast, but no better method of testing the threads of nuts is known.

This method of projection has a notable advantage over and above those derived from its ease and accuracy. Many makers at first found great difficulty in producing screw gauges of the requisite form and, having no adequate means of testing them, were inclined to dispute the decision of the testing authorities when they were rejected. But seeing is believing; a visit to the laboratory and a demonstration of the difference between the shadows of the rejected and the ideal screw soon convinced them that their accusations were unfounded. It was largely owing to these improved methods of test, which enabled makers to be told where the faults of their gauges lay, that the percentage of gauges passing the test rose from 20 per cent. at the beginning of the war to 75 per cent. at the end of it.

(*g*) Manufacture.

The making of gauges does not differ essentially from the making of any other metal object to a prescribed form; the only difference lies in the greater accuracy of the result which is required. The usual machine tools are used, lathes, milling machines, grinding and lapping machines, and so on, and the usual hand methods for the final adjustment. It is found that almost any skilled workman can produce gauges of any required form and accuracy, provided that he is provided with suitable means of measuring his work as it approaches completion. A testing department equipped with all the latest devices is necessary for the production of work of the highest class, and much of the work of the central testing departments has been concerned with advising manufacturers on the best methods of measurement for their special needs.

Their advice has been specially needed in connection with the making of screw gauges. Screw gauges, like all other screwed work, are produced by two methods, which are often combined. The first method is that of the screw-cutting lathe, in which a cutting tool is moved along the surface of the work, as it is rotated, by means of a "leading screw," usually operating through gearing, which forms an essential part of the lathe. The second method is that of the "tap" and "die." A tap is a plug of hardened steel, on which is cut a screw of some desired form, interrupted along lines parallel to the axis and provided with cutting edges, so that when forced into a plain cylindrical hole of suitable size it cuts a corresponding screw thread on the inside of the hole; a die is a screwed ring into which a rod can be forced so as to produce a corresponding thread on its surface. In both these methods the accuracy of the work produced depends on the accuracy of the tool by which it is produced. As soon as manufacturers all over the country were set to produce screw gauges it was found that the tools they possessed were surprisingly inaccurate; it was not uncommon to find screw-cutting lathes, supposed to be of a high class, in which the pitch of the leading screw was found to be in error by as much as 2 parts in 1000, an amount entirely impermissible in gauge work. These errors had often escaped notice because they would not affect greatly the fit of two threads produced by the same lathe, but only the fit of threads produced by different lathes. Excepting such very rough work as standard bolts and nuts, factories had only produced screws for their own use, and interchangeability with the work of other factories was unimportant.

An inaccurate tap or die can only be rejected, but inaccuracies in leading screws of lathes can often be corrected. In the early days of the war much of the time of the staff of the central testing laboratories was occupied in travelling about the country, setting up apparatus for testing screw-cutting lathes, and advising how the errors found might best be corrected. Their efforts not only made the production of large numbers of screw gauges possible, but also led to a permanent improvement in the accuracy of engineering work of all classes.

(*h*) Materials.

A word should be added concerning the material employed for gauges. As usually happens, the qualities which would be possessed by an ideal material are mutually inconsistent. It should be much harder than the material of the work to be tested, in order that it may not wear in contact with it; on the other hand, it should be easily worked. These qualities can, of course, be combined in some measure by using steel, which can be worked when soft and then hardened; but unfortunately the hardening is apt to produce distortion. This objection can be overcome to some extent, and was overcome in screw gauges, by hardening the steel on the surface only, case-hardening as it is called, but often hardening after making was not possible. Further, the supply of the most suitable forms of steel has been very limited, and what was available had often to be devoted to other objects; accordingly gauge-makers have actually used steels of all kinds from

plain carbon and mild steel to special alloy steels, their choice being dictated by what they could get rather than by what was best suited for their purpose.

It may be noted that for gauge work of the very highest class the gauge should be of the same material as the object gauged ; for if they are not of the same material they will expand and contract differently with change of temperature, and the gauge will be strictly correct at a single temperature only. But the range of probable temperatures has been so small and the permissible errors relatively so large in the manufacture of munitions that errors arising from this source could be neglected. But there was one consideration, not of a mechanical nature, which sometimes determined the material of the gauge. Picric acid, the explosive which, during the earlier part of the war at least, was largely used for filling shell, forms with iron a chemical compound which is liable to detonate with the slightest shock and explode the rest of the mass. Accordingly, the explosive must not be allowed to come into contact with iron ; and when shells already filled had to be gauged, iron was not permissible as the material of the gauge. In these cases a hard alloy called phosphor bronze was used, containing copper, tin and a little phosphorus, substances which are not so readily attacked by the explosive.

II. The Supply of Gauges.

(*a*) Supply prior to the Formation of the Ministry.

Before the war, all inspection gauges, with their corresponding checks, were made by the Ordnance Factories. Gauges for the inspection of guns and gun ammunition were kept at Woolwich Arsenal, where inspection of munitions for the most part took place. There were, however, several outstations, and to these examiners from Woolwich were sent when required with the necessary gauges. Inspection of small arms took place at Enfield Lock, where the gauges for these stores were kept. Contractors were responsible for obtaining their own shop gauges, which they either made in their own tool-rooms or bought from recognised gauge-making firms.

This simple system proved entirely insufficient to cope with the increased demand at the outbreak of war. While contractors continued to supply their own shop gauges, though with increasing difficulty and delay, the Chief Inspector soon found it necessary to decentralise inspection, and to extend the sources for the supply of inspection gauges The congestion at Woolwich, and the formation of local bonds for inspecting samples, made it necessary for inspection of gun ammunition to take place locally. The Ordnance Factories at first continued to supply the gauges, which were issued from Woolwich as required. but they could not manufacture fast enough to meet the demand (though their output went up 200 per cent. to 300 per cent.), and large orders had to be placed with gauge-making firms. By the middle of 1915 the number of inspection gauges required had grown far beyond the capacity of Woolwich, and contracts were being so widely placed that it was hardly desirable that a department which was not a contract

department should deal with them.[1] Accordingly, when the Ministry was constituted, it took over the whole question of gauge supply. Gun gauges were left in the hands of the Chief Inspector, and the supply of gauges for small arms was placed under the direction of Colonel Halse. The provision of gauges for gun ammunition and certain components was undertaken by the supply department for these stores (A.M. 3), which organised a special Gauge Section (A.M.3.D.) to deal with the question. On June 15th, 1915, Mr. M. F. Ryan was appointed head of the section. Its activities developed so rapidly that on May 16th, 1916, it was decided to organise it into a separate department (A.M.8) attached to D.D.G. (A), with Mr. Ryan as Director of Munition Gauges.[2]

(*b*) The Work of the Gauge Department.[3]

As the output of shell and components is relatively much larger than the output of other munitions, the Gauge Department had by far the biggest problem to face. The gauges for gun ammunition are bewildering in their number and variety. For the body of an average shell about 30 different gauges are required. For components the number is, in many cases, considerably higher. The complicated mechanism of a time fuse requires 160 different gauges, and the simpler graze fuse requires 100.[4] Moreover, as one set of gauges can only deal with a certain number of stores, increased production involves a corresponding increase in the production of gauges. One set of inspection gauges for 6 in. shell should deal with about 1,500 shells per week, therefore a factory like the Lancaster National Projectile Factory, whose estimated output was 6,000 per week, would require at least four sets of inspection gauges for this nature of shell alone.[5] Some of these gauges would last for a considerable time without renewal, but others would be inaccurate after three weeks' night and day wear, and would then have to be replaced.

Thus the department had to provide gauges in great numbers, and of extraordinary variety. It concentrated its energies in the first place on the supply of inspection gauges. As regards the gauges required for miscellaneous stores for use at Woolwich itself, it was decided to leave these to the Chief Inspector, while the Gauge Department took over the supply for inspection of important stores, inspected chiefly at makers' works and local bonds. In July, 1915, it was found that enterprising firms were already making their own inspection gauges,[6] so it was suggested that the system should be extended, and all contractors and boards of management should be required to provide their own inspection gauges, as well as their own shop gauges.[7] They might either obtain them locally or through the Ministry of Munitions, who would supply them at practically cost price.[8] It was hoped that

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[1] 94/G/480.

[2] Hist. Rec./R/263. 31/7.

[3] For convenience the term Department is used throughout to designate the Gauge Section of A.M. 3 as well as the Gauge Department, A.M. 8.

[4] *Ministry of Munitions Journal*, December, 1916.

[5] Hist. Rec./R/1121/23.

[6] C.R./1306.

[7] 94/G/480.

[8] Hist. Rec./R/1121/23.

the adoption of this system would lessen the congestion in gauge supply, which was now one of the chief factors in delaying output. The arrangement, however, which came into force in September, did not achieve its object; for most contractors found it impossible to obtain inspection as well as shop gauges locally, and applied to the Ministry to meet their requirements.[1] Where contractors attempted to make their own gauges, great delay ensued, for many of them were small and inexperienced firms with no facilities for such accurate work. Prices, moreover, were forced up, as the contractors expected to be paid for the inspection gauges out of the profits of the contract, and the number of rejections made the cost of the gauges extremely heavy.[2] In December, 1915, the system was once more re-organised. Contractors were no longer required to provide their own inspection gauges, which were in future to be obtained from the trade by the Gauge Department, verified by the National Physical Laboratory, and supplied to the Assistant Inspectors of Munition Areas, who would be responsible for maintaining sufficient supplies. Thus an arrangement, characterised by General Minchin as "a most objectionable system," was brought to an end, and contractors were freed entirely from the responsibility of suppplying their own inspection gauges. At the same time it was agreed that the gun ammunition gauges required at Woolwich and its outstations should be obtained also through the Gauge Department, and thus from January, 1916, the Ministry took over entirely the provision of inspection gauges for gun ammunition.[3] Contractors could, however, on application to the Department, still secure inspection gauges for shop inspection purposes; but these, though identical with inspectors' gauges, were stamped with a different certification mark by the National Physical Laboratory, to prevent their being used by Government inspectors.

At first shop gauges were left to the contractor as before, though the Ministry furnished guidance in design and construction where possible, and put contractors who could not make their own gauges into touch with gauge-makers who could supply their needs. In March, 1916, the Gauge Department undertook to supply shop gauges for the more important types of gun ammunition to contractors whose output was being delayed through inability to obtain them themselves; and, as soon as reasonable quantities of inspection gauges were forthcoming, it turned its attention to extending and organising this central supply of shop gauges. This was to some extent made necessary by the development of the National Projectile Factories, some of which required considerable assistance from the Gauge Department in obtaining their supplies, but it was also in the interests of rapid and economical production that shop gauges should be standardised and turned out in large quantities by a few firms with suitable plant instead of being produced as a bye-product by shell-makers. Accordingly in September, 1916, it was decided that standard gauges for all the more common

[1] (Printed) *Weekly Report*, No. 7 (11 September, 1915), p. 17.

[2] 94/G/480.

[3] (Printed) *Weekly Report*, No. 23 (1 January, 1916), p. 16.

types of gun ammunition and components should be designed by the Gauge Department, manufactured by its contractors, and kept in stock for immediate issue.[1] The majority of these standard gauges were simple in design and easily and cheaply procurable, so that shell-making firms adopted them in many cases. By January, 1917, there was such a large demand for standard screw gauges that as a temporary expedient inspection gauges specially marked had to be issued to manufacturers for workshop use.[2] Firms who wished to continue using their own gauges were, however, allowed to do so, uniformity, though considered desirable, not being insisted on.

In the early part of 1916 the activities of the Gauge Department were extended to include the supply of gauges for trench warfare ammunition.[3] In February, 1917, certain branches of the Admiralty asked for assistance in obtaining gauges for mines. Large supplies were urgently required for the new programme, so the department undertook to give them special preference. The first delivery was made by February 17th, and in May it was reported that, with the exception of a few screw gauges, provision had been made for all the types required.[4] In February also the Aeronautical Engine Section asked the department to provide the gauges required for aircraft production, and this demand was also met without interfering with the supply for gun ammunition and components, the situation with regard to these gauges being well in hand.[5] Shortly afterwards the provision of gauges for gun repairs was included in the department's work. By the end of March the delivery of adjustable horseshoe gauges (*i.e.*, gauges of special form for parts not easily accessible) had begun, and gauges for the re-tubing and re-boring of guns were in hand. Special designs for certain gauges for the bore of guns had to be made, and orders for these gauges were placed with one of the Government factories.[6] Subsequently the supply of some of the gauges for new guns required by Woolwich was undertaken by the Gauge Department, as well as certain "special" gauges required by the Mechanical Transport Department, the Department of Requirements and Statistics and the Inspection Departments in France, Switzerland, United States of America and Canada, so that the supply of gauges of all kinds was mainly controlled by the Ministry.

(*c*) Development of Sources of Supply.

In view of the urgent demands for gauges which reached the Gauge Department from all quarters, the development of the sources of supply

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[1] (Printed) *Weekly Report*, No. 59, III. (12 August, 1916).

[2] *Ibid.*, No. 76, II. (20 January, 1917).

[3] *Ibid.*, No. 24 (8 January, 1916), p. 17. Hitherto the Department had usually provided its own gauges.

[4] (Printed) *Weekly Report*, No. 78, II. (3 February, 1917); No. 80, II. (17 February, 1917); No. 90, II. (5 May, 1917).

[5] *Ibid.*, No. 78, II. (2 February, 1917); No. 79, II. (10 February, 1917).

[6] *Ibid.*, No. 83, II. (10 March, 1917); No. 84, II. (17 March, 1917); No. 85 II. (24 March, 1917); No. 97, II. (23 June, 1917).

was a matter of primary importance. The Ordnance Factories continued to provide the gauges required at Woolwich, but only a certain proportion of the Arsenal needs could be supplied by them. In August, 1916, through the efforts of the Gauge Department, arrangements were made with the Chief Superintendent to extend the gauge shops at the Royal Laboratory, and a large new shop was installed which gave additional assistance both to the Arsenal and to the Gauge Department. But previous to this extension, the percentage of orders that could be executed by the Ordnance Factories was very small, and the Ministry had to rely on private firms for the bulk of its supply.

When the Gauge Department was set up, the few existing gauge-making firms were already executing orders to the limit of their capacity, and the Department had, therefore, to persuade a number of new firms to turn their energies to gauge-making. The big ordnance, machine-tool and machine manufacturing firms, with one or two notable exceptions like the Coventry Ordnance Works and the Singer Manufacturing Company, were doubtful as to the possibility of extending their manufacture of gauges, and the proportion of gauge orders placed with firms like Messrs. Armstrong, Whitworth, and Messrs. Alfred Herbert was extremely small. The latter firm has since, however, accepted large orders. The Department had, therefore, to adopt the policy of distributing orders over a number of firms, of which about 150 eventually succeeded in producing satisfactory work.[1] Though engineering firms of all kinds predominated, gauges were turned out in curious and unexpected quarters. The Gilmore Dental Appliance Works, Edinburgh, the Gillette Safety Razor Company, and the Victory Dress Fastener Company are examples of firms whose ordinary trade was far removed from the work which they undertook to assist the Ministry. Machine-makers of all kinds, such as the British United Shoe Machinery Company, Messrs. Cotton, Messrs. Mellor, Bromley, and Messrs. Gamble, hosiery machine builders, proved a reliable source of supply for the simpler types. Clock and watch makers and cycle and motor manufacturers were also very successful. Side by side with big manufacturers like the Coventry Ordnance Works are found individual craftsmen like Michael Pedersen, of Dursley, who designed and constructed new machinery in order to turn out screw gauges,[2] and E. A. N. Pochin, of Chelmsford, who took an order for rifle gauges, and met the Contracts Department's request to state his prices with the embarrassing reply, " I am absolutely ignorant of the figures which obtain for this class of work, and am perfectly satisfied to leave you to fill up the contract at any price which you consider fair."[3]

The railway companies were not overlooked as an additional source of supply, but though several companies made efforts to help, their plant proved unsuitable, and for the most part they abandoned the attempt. One company, the Lancashire and Yorkshire Railway,

[1] *Ministry of Munitions Journal*, December, 1916.

[2] 94/G/1222.

[3] 94/G/1683.

succeeded in turning out satisfactory gauges, and the Great Western Railway was producing a small number of screw gauges at the end of 1917.

Educational institutions were also pressed into service. The Cambridge University Engineering Laboratory rendered yeoman service in making gauges for fuses of different types, while the University College of South Wales produced very satisfactory gauges of straightforward design.[1] Rifle gauges were made in large numbers by the Northampton Polytechnic Institute at Clerkenwell, and at the Manchester Municipal School of Technology.[2] In December, 1916, the L.C.C. Technical Institutes were delivering some 700 gauges a week,[3] and since then some of them have developed an output of difficult screw gauges.

The Post Office Factory and several municipal undertakings were another source of supply. In July, 1915, the Vice-Controller of Post Office Stores suggested to the Ministry that the tool-makers and highly skilled mechanics at the Post Office factory could be partly employed on gauges. The Ministry gladly accepted the offer, and orders for some of the more difficult gauges were placed.[4] The Glasgow, Preston and L.C.C. Tramways are examples of municipal enterprise, executing orders for gauges for components, shell, and Stokes bombs.[5]

The great difficulty experienced by the Ministry in obtaining enough screw gauges led to the opening up of foreign sources of supply. In June, 1915, a Swiss engineer resident in England offered to supply gauges if these could be made in Switzerland. After negotiations with the French Government it was decided that all Swiss firms and agents should make proposals through Mr. Angus, then British representative at Berne, who would act in concert with the French and Swiss authorities.[6] Diplomatic obstacles being thus cleared away, the Ministry placed orders in Switzerland with several firms, and satisfactory results were obtained from La Société Genevoise and, in certain instances, from M. Pierre Roch, of Berne. Swedish gauges began to come in at the end of 1915, the Department having been successful in securing the services of M. Johansson, the well-known maker, whose screw gauges were very satisfactory.[7] Several attempts were made to secure gauges from France and Holland at this time, and special visits were paid to these countries by representatives of the Department for this purpose. In 1917 the demands of the Aeronautical Department for metric screw gauges led the Ministry to send further representatives to France and Switzerland to persuade the leading gauge makers there to undertake these, while visits were also made to

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[1] Order and Supply Lists, Supplements 3 H, 7 H., 11 H.

[2] Order and Supply Lists, Supplements 3 H, 7 H, 11 H.

[3] *Ministry of Munitions Journal*, December, 1916.

[4] 94/G/420.

[5] Order and Supply Lists, Supplements 3 H., 7 H., 11 H.

[6] 94/G/360.

[7] (Printed) *Weekly Report*, No. 23 (1 January, 1916), p. 16; No. 51, III. (22 July, 1916); No. 31 (26 February, 1916).

American firms to secure their services in manufacturing screws of various types. In June the first consignment of metric gauges from France came to hand and was reported to be satisfactory, and this afterwards developed into a reliable source of supply. The prospects in America were less hopeful, as the Ministry's representative did not report very favourably on the facilities for manufacturing to the close limits specified. Orders were, however, placed with several firms,[1] and good deliveries were being made in March, 1918.

(*d*) Difficulties of Supply.

Apart from the general inexperience of makers, the difficulties which confronted the Department in obtaining large quantities of gauges were chiefly two :—

(1) The shortage of skilled labour.

(2) The lack of precision tools.

(1) Much of the work in gauge-making has to be to such fine limits that it can only be done by highly skilled labour. In the first twelve months of war this was at a premium, and, in addition, the actual number of experienced gauge makers was exceedingly limited. Consequently many firms refused to undertake the work at all, and others, who accepted gauge contracts, though very successful in other work, failed to produce satisfactory gauges, and had to ask for the cancellation of their contracts. Typical instances are those of Messrs. Braun & Company, who, when urged to take up the manufacture of rifle gauges in September, 1915, said it was practically impossible to get gauge-makers and first-class fitters and turners, and the Power Plant Company, who asked to be relieved of a contract for gaine gauges because they found it impossible to get men to do the work.[2]

Another result of the labour difficulty was the inability of firms to give the delivery required by the Ministry. In order that the work might be put in hand as quickly as possible, the Gauge Department sent firms an authorisation to begin work before the formal contract was signed.[3] In this " Gauge Order," the approximate date by which delivery was to be completed was stated. For an order of 20 to 50 gauges six weeks from the date of the receipt of the official drawings was a common time specified. But the extreme accuracy required by the Inspection Department made it impossible for makers to do more than rough out the bulk of the gauges until their samples had been passed. Thus in many instances the time specified in the gauge order had elapsed before any appreciable amount of work had been done, and the date of delivery had to be reckoned from the passing of the samples rather than from the receipt of the official drawings. For instance, on 28th July, 1915, Messrs. Burton Griffiths & Co. were

[1] (Printed) *Weekly Report*, Nos. 88, 90, 91, 97, 98, 100 ; Section II. (April-July 1917).

[2] 94/G/590/512.

[3] See Appendix I.

authorised to put in hand three different types of gauges, delivery of which was to be completed in six weeks, and tender forms were issued in the usual way. After several requests from the Ministry, the firm forwarded the tender for one type with the date of delivery inserted as 9th October. When asked for the others they replied that, as the gauges were most difficult to manufacture and those turned out had not yet passed the National Physical Laboratory test, they could not quote either definite delivery or price. On 10th November these two orders had to be cancelled.[1]

As makers gained experience the labour difficulty was to a large extent overcome. Firms were pressed by the Ministry to dilute their skilled labour, and in most cases did so with good results. Women and boys were put on to rough out the gauges,[2] which were afterwards finished to the required limits of accuracy by skilled men. This plan was adopted by Messrs. Chatwin, at whose works women did the roughing out to within ·006 of an inch.[3] In some factories, as at Messrs. Pitters, where screw-cutting lathes were worked by women, the women, under the supervision of skilled men, were able to perform many of the finishing operations as well,[4] and showed themselves capable of cutting threads correct to ·0003 in.[5] At the end of 1918, about 80 women were employed in the Wolseley National Gauge Factory on what was previously considered skilled men's work. In many instances, manufacturers were able to train their ordinary mechanics to the higher skill necessary for gauge-making (*e.g.*, Messrs. Pitters and the Wolseley Motors, Ltd.), and this helped to relieve the situation. The labour supply, however, must always present somewhat of a problem in gauge manufacture owing to the high degree of skill required.

(2) The second great difficulty was that precision machinery, such as accurate lathes and grinders, was practically non-existent, and could not easily be procured. This was especially the case with regard to screw-gauge machinery, as before the war the manufacture of screwed parts to fine limits was not customary to any great extent in England. Thus, though there were firms willing to undertake the simpler types like plug and ring gauges, very few would take orders for screw gauges. Orders for complete sets were therefore hardly ever placed. In August, 1915, Messrs. A. Herbert executed an order for 50 complete sets of fuse 100 gauges at a total cost of £954 12s. 11d., and Messrs. Barber & Coleman took a similar order at £966 16s. 10d.[6] But in general orders were placed with different firms for the particular types of gauges most suited to their plant and the skilled labour at their disposal, the quantity ordered varying as a rule from 10 to 100 of a type.[7]

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[1] 94/G/478.

[2] The introduction of women into the actual work of gauge-making was comparatively late, being tried in the latter part of 1916, and considerably developed during 1917. Women were, however, employed to examine the gauges when made early in 1916.

[3] L.I.B./C/309/1.

[4] L.I.B./C/778/1.

[5] *Ministry of Munitions Journal*, November, 1917.

[6] Order and Supply Lists, Supplement 3 H.

[7] See Appendix I.

In time certain selected firms developed a much larger output *e.g.*, orders running into thousands were placed with the Coventry Ordnance Works and the Newall Engineering Company in January, 1916.[1]

The Gauge Department did its best to assist makers by getting machines from abroad, especially from Switzerland, but these were quite insufficient to meet the demand. Home sources of supply were next developed, Messrs. Alfred Herbert and others giving assistance in this respect. Simplified precision machines were designed and built, and this has resulted in the possibility of producing gauges, particularly screws, in several ways. Messrs. Pitter's experience may be quoted as an example of the effect on output of these machines. The screw-cutting machine designed by Mr. Pitter and installed in his new workshops cut eighteen to twenty soft steel screw gauges a day, whereas the men working on ordinary lathes in the old shops were only able to produce one or two a day.[2]

As a result of these improvements and of the Department's policy of concentrating the entire energies of the most successful makers on screw gauges, the difficulty has been to some extent overcome, and a more than sufficient supply would have been available had it not been for heavy but unforeseen demands for screw gauges for aero-engines. The home output could, however, be materially increased if more precision plant were available.

(*e*) Financial Arrangements.

Though the Ministry encouraged makers in every way by giving expert advice in manufacture, assistance in obtaining machinery and material and "sympathetic consideration" to requests for extension of time for delivery, many contractors were unwilling to develop gauge-making because they felt that if they took orders on the ordinary contract basis, they would lose heavily owing to the number of rejections they would inevitably have at first, and to the large amount of time and material wasted in manufacture. To meet this objection the Ministry adopted the system of payment on the cost and percentage profit basis. Firms who had not manufactured gauges before were offered contracts on the basis of "actual labour cost, plus 100 per cent. for overhead charges, plus costs of material, plus 10 per cent. on the total." Thus contractors were safeguarded from loss on labour and material, and were guaranteed a certain margin of profit. The majority of the early orders were placed on this basis, though fixed prices were adopted in the case of large and experienced firms wherever possible.

After a short experience of these contracts firms began to raise objections to them on the ground that 100 per cent. was not necessarily sufficient for overhead charges; and, in some cases, they also considered the profit allowed insufficient. As a rule when complaints of this kind were received, the Ministry offered to substitute a contract at a fixed price if the firm would quote figures. In July, 1915, several firms

[1] 94/G/1129/1298. [2] L.I.B./CE/778/1.

changed from cost plus percentage contracts to contracts at a fixed price,[1] and this was constantly occurring during the next few months. This did not, however, entirely meet the case of inexperienced firms. Many who found 100 per cent. overhead charges insufficient could not quote fixed prices as they had no data on which to work, or if they quoted, they made such big allowances for contingencies that the price named was excessive. Accordingly, the terms of payment in the cost plus percentage contracts were altered. This was done at first only in exceptional cases. Thus, an increase in overhead charges was sanctioned in the case of the Wolseley Motors, Ltd., who were allowed 125 per cent. for overhead charges early in 1916; and an increase in profit was sanctioned in the case of a South Tottenham contractor, who was allowed 15 per cent. profit on a contract for rifle gauges.[2] Such changes were made necessary either by the intricate nature of the gauges or by the difficulty of obtaining adequate supplies. In March, 1916, this widened interpretation of the cost plus percentage contract was given a general application, the clause defining the payment to be made running as follows: "Actual *productive* labour cost, plus *such percentage thereon as represents the proportion of the actual overhead charges applicable to such labour cost*, plus *net* cost of material, plus 10 per cent. on the total." In specific instances, however, makers preferred to have the percentage still definitely fixed at 100 per cent. This was the case with the Cambridge Engineering Laboratory and the Perforated Music Company. The Ministry complied with their wishes, the Auditor remarking with regard to the latter that "the Ministry will be well advised in accepting 100 per cent. as the rate of on cost. The actual rate is considerably more."[3]

The cost plus percentage contract was only adopted to meet a difficult situation, and the Ministry's policy was to eliminate it as much as possible. As soon as firms had had a fair amount of experience in making a certain type of gauge, they were asked to quote a fixed price on repeat orders. Between July and September, 1915, the majority of orders were placed on the cost plus percentage basis, but by March, 1916, fixed prices predominated. An example may be quoted in December, 1915, when the Pitter Engineering Company wished to execute a repeat order on the cost plus percentage basis. The Ministry said, however, that as the firm had had considerable experience in the manufacture of the type of gauge ordered, they should be in a position to quote, and the order was placed at a fixed price.[4] On the other hand, the Ministry permitted some firms to continue on the cost plus percentage basis. In January, 1916, Messrs. Bassett Lowke were asked to quote, but were afterwards allowed to do the work on the cost plus percentage basis, the reason apparently being that, as labour was cheap at Northampton, the percentage basis was as economical as the fixed price.[5] With regard to the Gilmore Dental Works, who asked that *all* orders should be placed on the cost

[1] 94/G/389.
[2] 94/G/1215/1401.
[3] 94/G/1295.
[4] 94/G/1078.
[5] 94/G/1071/1315.

plus percentage basis, the Auditor said it was most advisable to continue the arrangement, " in every case their prices are lower than any other contractor."[1]

In the case of contractors who had few rejections, the price on the cost plus percentage basis worked out very reasonably, but when contractors had gauges returned two or three times, and the Ministry had to pay for the labour required to rectify them as well as for the material wasted in manufacture, the cost plus percentage arrangement was very extravagant. At the end of May, 1916, it was laid down as a general rule that " only very special circumstances . . . . can justify any proposal to pay contractors on a basis of cost, plus percentage of profit."[2] An exception was made in the case of gauges, owing to the special character of the work, but the Finance Department expressed its opinion that the number of these contracts should be kept as low as possible.[3]

The definite fixing of prices gave the Ministry an opportunity of trying to reduce prices, and provided a basis of comparison. On the whole the prices quoted were fair and reasonable, but in a minority of cases they were high, and the Ministry then asked for a reduction. In some cases the firms acceded to the request without any demur. On 15th March, 1916, for instance, Messrs. G. Cusson, Ltd., tendered for 25 6 in. shell caliper gauges at £12 each, but as Horstmann Cars, Ltd., were doing the same gauges at £8 15s. each, the Ministry suggested a reduction of £2 per gauge, and this was accepted by the firm.[4] But often firms refused to alter their price, saying that the intricate nature of the work and the extreme accuracy required made it impossible to make the gauges for less. In the early days of the Ministry, if firms stood out for their prices the Ministry had to accept them, owing to the urgent need of the gauges and the impossibility of obtaining them elsewhere. Thus, in August, 1915, the Gauge Department objected to the prices quoted by Messrs. Muir and Company for screw gauges. The firm answered that rather than do the work at a lower price they would not take the order at all, whereupon the department had to accept their terms.[5] In October a contract was placed with the British L. M. Ericsson Company at relatively high prices, because, as the department stated, " we may not get the gauges elsewhere in time."[6] Again, in November the Ministry had to accept the terms offered by Messrs. Tilling Stevens, because there was no other contractor who would make the particular type of gauge required.[7] As the organisation improved, and the sources of supply grew more assured, the Ministry was able to fix maximum prices successfully. It is difficult, however, to show how far the reduction in price was really steady, partly because contracts for the same gauge were placed sometimes at fixed prices and sometimes on the cost plus percentage basis, and

[1] 94/G/1836.
[2] 94/G/2199.
[3] 94/G/2199.
[4] 94/G/1556.
[5] 94/G/546.
[6] 94/G/756.
[7] 94/G/978.

partly because individual circumstances, numbers ordered, and urgency of delivery affected prices considerably. The Ministry's policy was to induce individual firms to lower their prices as they gained experience and were able to execute larger orders, rather than to make all firms conform to a uniform standard, which would obviously have been an unsound policy. The general tendency of prices was downwards, and by the end of 1916 average prices were considerably lower than those ruling in 1915.[1]

Contracts other than those with the trade were placed on varying bases. The University Engineering Departments and the Technical Institutes took contracts either on the cost plus percentage basis or at fixed prices.[2] Orders with foreign firms were placed at a fixed price, generally with the proviso that 75 per cent. or 80 per cent. should be paid on delivery and the remainder after the gauges had passed test in England.[3] Orders with Railway Companies were placed through the Railway Executive Committee at agreed prices.[4]

(*f*) The Supply of Raw Material.

In general tool or high grade steel is used for making gauges, which have hardened working surfaces; but during 1917 and 1918 the practice of making gauges of mild steel and then case hardening them found greater favour on account of the reduced cost of material and the greater ease in machining mild steel. In the early stages of manufacture screw gauges, with certain exceptions, were not hardened, but as a result they lost their accuracy very soon and had often to be renewed. It was found impossible to procure hardened screws in any quantities because so few firms had the necessary experience. Hardened gauges were also considerably more expensive, as is shown by the fact that a gauge made by Messrs. Bassett-Lowke for £2 2s. (unhardened) cost £4 5s. when made by the Coventry Ordnance Works with its working surfaces hardened. As, however, the hardened gauge would last three or four times as long as the soft one, the price was pronounced reasonable by the Gauge Department.[5] In certain cases arrangements were made to have screw gauges toughened by a process invented by the Westminster Electrical Testing Laboratory, with the result that the life of the gauge was considerably prolonged.[6]

The need for economy and the difficulty experienced by many firms in obtaining steel led to experiments being carried out by the Lea Foundry Company in 1916 with the object of substituting chilled cast iron for steel in the manufacture of ring and plug gauges. In September, 1916, the result of the experiments was reported to the Gauge Department. A few of the gauges had been successfully ground and passed, but most had failed owing to the hardness of the material. Moreover, the amount of personal attention required made

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[1] See Appendix II.
[2] Order and Supply Lists, Supplements 3 H, 7 H. and 11 H.
[3] 94/G/483/1020/1842/1902.
[4] 94/G/481.
[5] 94/G/2316.
[6] 94/G/1801.

most gauge makers hostile to the idea, and it was decided to abandon it.[1] Another attempt to use cast iron was made in 1917, when it was reported that the firm was successfully producing cast iron gauges of various kinds,[2] but it was eventually dropped as being unsatisfactory. Cylinder gauges have, however, always been successfully made in large quantities of cast, but not chilled, iron.

(*g*) Summary of Output.

Between August, 1915, and December, 1917, approximately 760,000[3] gauges, comprising 14,500 different types, were delivered by contractors to the National Physical Laboratory for testing. This figure does not represent the total output of gauges for the period, since all rifle gauges were sent to Enfield Lock, and gun gauges, as well as certain gun ammunition gauges, went straight to Woolwich. On the whole the average weekly delivery per month shows a steady increase. In January, 1916, it was approximately 3,330 and by December it had reached 5,530. In July, 1917, the delivery reached high-water mark, the weekly average for the month being 11,015. During the remaining five months of the year there was a slight decline, but the average weekly delivery remained in the neighbourhood of 10,000. During 1918 there was a decided decrease in the numbers of gauges dealt with by the National Physical Laboratory. The highest weekly average was 8,000 in January; by October it had fallen to 6,600; while after the signing of the Armistice there was a quick drop to 4,700 in December, 1918. Approximately 326,000 new gauges of different types were tested during the year, 73 per cent. of which passed, compared with 75 per cent. in 1916 and 1917. The slight falling off in efficiency in manufacture in 1918 was probably largely due to the greatly increased dilution of labour during that year.[4]

III. National Gauge Factories and Assisted Contracts.

In spite of the progress in manufacture made by many firms, the obvious weaknesses inherent in the system of spreading contracts for small quantities of gauges over a large number of firms, together with the paramount necessity of increasing the supply of screw gauges, led the Department to consider the possibilities of greater concentration in manufacture and more rigid control over the producing factories. As early as July, 1915, the establishment of a Central Gauge Factory was suggested,[5] and on several other occasions the idea received serious consideration. But when it was first brought forward, the urgency of supply was so great that the time required for building and equipping such a factory, and the difficulty of finding the necessary

[1] 94/G/1558.

[2] *Ministry of Munitions Journal*, March, 1917.

[3] N.P.L. Statistics.

[4] Appendix III. The figures given here and in the tables in the Appendix can only be regarded as approximate.

[5] C.R/971.

staff, made its adoption impossible. Though these obstacles disappeared to some extent later, the scheme was never carried through, as it was felt that the interests of production would be better served by selecting certain of the successful makers and aiding them to extend their works and improve their output.

This policy resulted in the establishment of National Gauge Factories. Generally speaking, the buildings of the selected firms were taken over and in many cases extended, and their organisation was controlled and financed by the Ministry. But the agreements varied very considerably in detail to meet the widely different circumstances of the managing firms, and the result was that, as time went on, it became uncertain as to whether certain factories were National Factories or merely Controlled Establishments. In February, 1918, the Controlled Establishments Division stated that "the principle on which this Department has proceeded is that when the factory is carried on on behalf of the Government it is properly considered a National Factory . . . . but that where merely the whole output is taken and the firm paid for that output, the premises do not constitute a National Factory."[1]

Under this definition the term National Factory embraced six factories in all—the Woolwich National Gauge Factory, the Birmingham National Small Tools Factory, and the Croydon, Wolseley, Fairfax, and Newall National Gauge Factories.[2] It should be noted, however, that the National Gauge Factories were not on quite the same footing as the new national factories devoted to the production of ammunition, since they were not fresh organisations unconditionally established and owned by the Government. A central gauge factory, had it been established, would have been a national factory of this type; as it was, the nearest approach to such a factory was the Fairfax Gauge Factory, established directly by the Ministry in 1917.

(*a*) The Woolwich National Factory.

The works owned by Messrs. Pitters Ventilating and Engineering Company were the first to be placed under Government control. The first agreement, which was in July, 1915, only gave the Ministry partial control over the firm's activities, so a second agreement was made in August, 1916, which placed the firm's entire output in the hands of the Ministry. By the first agreement the firm was to erect new gauge-making shops (Brewer Street Works) adjoining their own private works. These new shops were to be entirely separate from the old works, and the whole output was to be under the control of the Ministry. The Government was to find the money for the erection and equipment of the buildings and for the working expenses of manufacture, excluding, however, the directors' fees and the managing director's salary. For profit the company was to have 20 per cent. of the total sum paid as wages and salaries by the Ministry.[3] By the second

[1] M.F./Genl. /1422. [2] M./Demob./21.
[3] D.D.G. (A)/15828.

agreement it was arranged that the Ministry should also take over the company's private works (Market Street Works). As, during the year 1915-1916, the Company had become involved in financial difficulties, the financial arrangements were put on an entirely new footing. The Ministry took over all the assets and trade liabilities of the firm, lent them a sum of £5,000 to clear their overdraft at the Bank, and, as remuneration for their services, agreed to pay them a sum of £2,000 a year with a bonus of £500 a year for economical working. Directors' fees and the managing director's salary were to be paid by the company as before, and one of the directors of the company was appointed a special financial director with an additional salary also to be paid by the company. The Ministry appointed a chairman, who was to act as its representative and control the company in its interest. The agreement was to remain in force for a period of five years from 1 April, 1916, but if the war should end before 1 April, 1919, the Minister might terminate it by six months' notice in writing. Such termination was not, however, to take place before 31 March, 1919. When the agreement came to an end the company was to have the option of purchasing the works at their current value, and was to repay the £5,000 loan in four annual instalments.[1]

In January, 1917, Messrs. Pitters were instructed to build an addition to the works for the purpose of making screw gauges, by means of a special machine designed by Mr. Pitter, which could be worked with unskilled labour. In this extension, which was completed by May, 1917, space was provided for 24 machines, but only 12 were installed at first to see if the output would prove satisfactory. A great deal of difficulty and delay occurred, the principal obstacle to success being that, as the supply of gauges increased, manufacturers refused to take the soft gauges made on the Pitter machines, and hardening had to be taken in hand. By the end of 1917 the chief difficulties were overcome, and during 1918 the additional machines were installed with a corresponding increase in output. During the summer of 1918 a further extension was planned for the purpose of making block gauges of the Johansson type, but the work, which was put in hand in October, was stopped on the signing of the Armistice.

No definite agreement had been made with the firm in connection with the extension of 1917, so in August, 1918, the Ministry put forward a draft agreement to cover this and the scheme for the new extension. Briefly put, this proposal was that the company should abdicate from its position as manager, and that the Ministry should take over the whole factory, carrying it on as a true National Factory under a manager (still to be Mr. W. C. Pitter) appointed by itself, and paying a rent for that part of the buildings and machinery owned by the company. After the termination of the agreement the company was offered the option of taking back from the Ministry the whole of the factory, including Government property as well as its own, on certain fixed terms.[2] This proposal was declined by the company, and therefore, when the

[1] D.D.G. (A)/15828. [2] Unregistered memo.

Armistice was signed in November, 1918, the agreement of 1916 was still in force for the Market Street and Brewer Street Works, and no agreement had been come to with regard to the later extensions. The factory continued to make gauges (chiefly for aeroplanes) until the spring of 1919, when the Ministry began negotiations with a view to arriving at a settlement with the company.

(*b*) The Birmingham National Small Tools Factory.

The agreement made with Messrs. Chatwin, of Birmingham, in September, 1915, was a much simpler one. Messrs. Chatwin were to extend their premises at a cost of £8,000, of which 70 per cent. would be repaid by the Ministry. The Ministry was to take over the control of the works from August 31st and advance working capital, and also take the entire output, as soon as the firm had completed outstanding contracts. Payment was to be made every six months on the basis of valuation of stock and work done, plus 15 per cent.[1] The Ministry was to appoint a Director to look after its interest.[2] From 1915 to the signing of the Armistice the factory was carried on under these conditions, though the capital expenditure considerably exceeded the £8,000 originally agreed upon. By December, 1917, it had reached £11,000 and it was estimated that it would reach a total of £12,000.[3] A greatly increased output was the result as well as a considerable profit to the Ministry. Of the six National Factories this was the only one where it was possible to ascertain the actual profit made. The greater part of the output of this factory consisted of small tools, taps and dies, and these were supplied at the Ministry's instructions to contractors engaged on munition work, and charged to them at standard trade prices. The profit made was, therefore, ascertainable in the same way as that of a private business. The whole output of the other five factories was sent to the National Physical Laboratory at Teddington, to Enfield, or to Woolwich, where the gauges were invoiced at cost, plus 10 per cent. profit. Thus the profits are shown as a percentage on the turnover, and no actual figures are obtainable.

After the signing of the armistice it was arranged that Messrs. Chatwin should resume control of the factory from 31 March, 1919. The reversion of the factory to the private owners was in this case a comparatively simple matter, since the work carried on during the war was the firm's normal business, and it was, therefore, simply a matter of financial settlement between the firm and the Ministry.

(*c*) The Croydon National Factory.

Negotiations with regard to the Croydon National Gauge Factory were started in November, 1915. The factory was originally owned and worked by Pintsch's Electrical Manufacturing Company, which was of German origin. As it had a skilled management and staff capable of producing most difficult gauges, the Ministry was approached to take it

[1] 94/G/707. [2] L.I.B./C/309/1. [3] C.R./2913.

over and carry it on as a National Factory. It was thought, however, that objections might be raised to the provision of funds for a business with German connections, and so the offer of a Mr. Pugh to form a company, which would be known as the Vidal Engineering Company, to take over the factory, finance it, and carry it on under the supervision of the Ministry was accepted.

According to the agreement of 1915, the company was to lease premises and provide a capital sum of not less than £5,000 or more than £10,000 for carrying on the manufacture of gauges, such capital to be treated as bearing interest at 1 per cent. over the current Bank of England rate. Provisional prices were to be fixed between the Ministry and the Company, whose books were to be open for inspection. Accounts were to be rendered and paid monthly. At the termination of the agreement any surplus profit was to be paid to the Ministry, and any loss would be made good by the Ministry. The Ministry could dispense with the company's services at any time by repaying the capital and taking over all liabilities.[1]

The financial arrangements were slightly modified in May, 1916. The provisional prices fixed by the firm were always considered far too high by the Ministry, and in March the Finance Department suggested that Mr. Ryan should fix the provisional prices. This was done on the next orders, but in May the company protested that to do the work at the prices proposed would involve them in a direct loss, as the establishment charges (which included writing off the machinery at the rate of £200 a month as agreed by the Ministry) were very high. To meet the difficulty, it was decided to pay for all gauges in future on the basis of productive labour, plus the ascertained on-cost, materials, and 10 per cent. of the whole amount for profit.[2]

Early in 1917 it was decided to extend the works. This decision, together with the fact that the company's expenditure had by this time considerably exceeded the £10,000 originally stipulated, and that Mr. Pugh had received nothing for his services beyond the agreed interest on capital expenditure, necessitated the drawing up of a fresh agreement. It was some time before satisfactory terms could be arrived at, so Mr. Pugh sent in a claim for remuneration for his past services, and was awarded £1,000 by the Lubbock Commission. The agreement, which was finally signed in October, 1917, cancelled the agreement of November, 1915. The existing arrangements with regard to the lease of the premises were to be continued, and also the agreement with Mr. Vidal to act as manager. Capital up to £30,000 was to be provided by Mr. Pugh, who was to continue to work the factory as agent for the Ministry. Either party to the agreement might terminate it and the capital would then be repaid. The price to be paid for gauges was the cost of labour and materials and overhead charges, plus 10 per cent. on the total as remuneration to Mr. Pugh for his services. At the termination of the agreement any surplus on the working of the factory after all liabilities had been discharged was to be paid to the

[1] 94/G/1087. [2] 94/G/1378/1943.

Ministry, while equally any deficit shown would be made good by the Ministry. Upon the repayment of the capital advanced and the discharge of liabilities all the plant, machinery and buildings erected by the Ministry would become its property. Mr. Pugh was to have the option of building, entirely at his own expense, a permanent addition to the factory, instead of the temporary one proposed by the Ministry, which permanent building would remain his property on the termination of the agreement.[1]

When work was started on the new building, it was found that the land on which it was proposed to build it was unsatisfactory. Mr. Pugh, therefore, put forward a proposal for building an entirely new factory in another place. This offer was accepted, and the October agreement was modified in November to meet the new situation. The lease of the Gloucester Road premises was to be ended, and the plant and machinery belonging to Pintsch's Electric Manufacturing Company, together with all the machinery belonging to the Ministry and some temporary buildings at Gloucester Road, were to be removed to the new factory, which was to be built at Mr. Pugh's expense and to remain his property on the termination of the agreement. Mr. Pugh was to undertake all responsibility for the arrangements with Pintsch's Electric Manufacturing Company. The Ministry agreed to pay a rental of £1,025 a year (the sum which had been paid up to this point to Messrs. Pintsch for the use of their premises and plant) for the use of the plant and machinery and new buildings, in addition to all other payments made under the existing agreements.[2]

In February, 1919, Mr. Pugh gave notice to terminate the agreement.

(*d*) Wolseley National Factory.

Under the agreement with the Wolseley Motor Company made in January, 1917, the company's factory at Pimlico was to be carried on as a gauge factory under the direction of a representative of the Ministry. The Ministry agreed to take over all the buildings that had been erected and all the plant that had been installed since September 30th, 1914, as well as the consumable stores and the gauges in the course of manufacture which were in the factory on January 20, 1917. The total sum to be paid for these items was £24,768 2s. 9d. The pre-war plant and buildings were to remain the property of the company, though the Ministry was to have the use of them. From January 20, 1917, the Ministry was to bear the cost of working and maintaining the factory, paying to the company £1,186 a year in respect of depreciation of pre-war plant and buildings, and as profit a sum of 20 per cent. per annum on the capital cost to the company of the pre-war plant and buildings, which was reckoned as £12,010 12s. 4d. As the company was, at the time of the agreement, making gauges for Messrs. Vickers, it was agreed that they should continue to do so at the discretion of the Ministry, all payments for such gauges being made to the Ministry. The agreement was to be binding for the duration of the war, but the

[1] 94/G/1000. [2] W.B./657.

Ministry reserved the right to terminate it at three months' notice if necessary. At the termination of the agreement all property belonging to the Ministry might be removed, and the premises as well as the plant belonging to the company were to be handed over in good repair.[1]

When the Ministry took over the factory, the plant was increased to double its previous capacity and was further added to afterwards, with a corresponding increase in output. On the signing of the Armistice notice was given to terminate the agreement, and the factory returned to its former business of motor-car repairing.

(*e*) Fairfax National Factory.

The Fairfax National Gauge Factory was established in May, 1917, to utilise skilled enemy labour in the production of check and other difficult gauges. Existing buildings at Kilburn were rented and added to by the Ministry, and operations were begun under the management of Mr. W. J. Bassett-Lowke, whose firm was already doing a great deal of gauge work. As far as the financing and auditing of the accounts were concerned, the factory was worked as an adjunct of the Wolseley National Gauge Factory. About 15 men were employed, with most satisfactory results from the point of view of production.

After the Armistice was signed the Home Office decided that the mechanics should be re-interned, and the factory was closed in January, 1919.

(*f*) Newall National Factory.

The Newall Engineering Company made gauges for the Ministry from September, 1917, on an assisted contract basis, but in the spring of 1918, it became evident that the parent company, Peter Hooker & Co., was using the Newall Works to assist in furthering its own post-war interests, and the output for the Ministry was suffering considerably on that account.[2] It was therefore decided to turn the works into a National Factory. An agreement was made in April, 1918, on the same basis as that with the Wolseley Motor Company. The Ministry was to take over the entire control of the factory, though it was to remain the property of the company. All consumable stores in the factory on 31 January, 1918, the date from which the control of the Ministry was to operate, were to be bought from the Company by the Ministry at actual cost price, plus 10 per cent. for storing and handling. All work in progress for the Ministry was also to be taken over and paid for on the cost plus percentage basis. Admiralty and private contracts then running were to be completed at the discretion of the Ministry, which would receive all payments for such work. From 31 January, 1918, the Ministry was to bear the cost of working and maintaining the factory, taking over the entire staff except the Works' Manager, who was either to be compensated or to be employed elsewhere. As profit the company was to have the sum of £9,000 per annum, beginning from the date of the agreement and payable

[1] 94/G/4986. [2] PM/Misc./384.

quarterly. The Ministry had the option of terminating the agreement at three months' notice, otherwise it was to remain in force for the duration of the war. At the termination of the agreement the company was to have the option of buying, at an agreed price, any additional buildings or plant which might have been erected during the occupation of the factory by the Ministry.[1]

On the signing of the armistice the works were handed back to the Newall Engineering Company, the work in hand, stock, etc., being transferred on the same terms as they had originally been taken over by the Ministry.

(*g*) Assisted Contracts.

Another method of increasing output adopted by the Ministry was the assisted contract. Agreements under which the Ministry advanced money for extensions of plant and buildings were entered into with the Coventry Ordnance Works (January, March, May, 1916), Messrs. Tilling Stevens (July, 1916), the Coventry Gauge and Small Tool Company, and Horstmann Cars, Ltd. (July, 1917). The money was either advanced directly by the Ministry, as in the case of Horstmann Cars, Ltd. (50 per cent.),[2] or paid indirectly by means of an increased price for the gauges supplied to the Ministry, *e.g.*, Coventry Ordnance Works (75 per cent.).[3] The difference between these firms and the National Factories was chiefly in the matter of control. The carrying on of the works under an assisted contract scheme was left in the hands of the company, whereas in the National Factories a director was appointed by the Ministry to protect their interests and to co-ordinate the work of the Gauge Department and the factory. Orders were placed on the ordinary contract basis, and though there was no stipulation as to the disposal of the gauges manufactured, in practice the Ministry took the whole output.

(*h*) National Factories under Local Administration.

Proposals were also made by the local Boards of Management of Liverpool, Leeds and Birmingham to establish central factories for the supply of gauges to shell makers in the areas under their control. The Liverpool scheme was the most important. The factory which was set up at Bootle[4] made workshop gauges for local requirements, but particularly for the Liverpool National Shell Factory, which formerly made its own gauges.[5] To some extent it was utilised by the Gauge Department for the supply of plain (*i.e.*, not screwed) gauges, both shop and inspection, but on the whole it was found that most of the gauges could be supplied by contractors manufacturing on a much larger scale, and therefore, presumably, at a lower rate. Prices, however, seem to have worked out very reasonably, since, when

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[1] PM/Misc./384. [3] 94/G/1367. [2] 94/G/6180; P.M./Misc./384.

[4] The factory was producing gauges in March, 1916, but the exact date at which it was set up has not yet been found.

[5] L.I.B./C/3955/1.

the costs for the first quarter of 1917 were submitted to the Ministry, they were said to compare very reasonably with the costs of other factories.[1]

The Birmingham Gauge Factory was really a department of the National Shell Factory. As early as November, 1915, the Board of Management decided to set up a gauge department of their own, and the shop was equipped and in working order by January, 1916. At first this shop only supplied the needs of the National Shell Factory, but as its output increased it was able to supply also firms in the area controlled by the Birmingham Committee. It has attained an average output of about 200 gauges a week, and since the beginning of 1917 it has, like the Liverpool factory, supplied certain gauges for the Ministry.[2]

The production of gauges in Leeds for local requirements was carried on in the same way as at Birmingham. The Gauge Department of the Ministry had, however, no control over these local enterprises, which were managed entirely by the D.A.O. Department.

IV. Effect of Changes in Design.

The continual alterations in the design of shells and components, especially fuses, inevitably affected the output of gauges and tended to check regular and rapid production. Early in 1916 alterations in the design of the 18 pounder and 4·5 in. H.E. shell caused a temporary decrease in supplies,[3] and in April it was reported that there would probably be a shortage of gauges for the altered marks of 4·5 in., 60 pounder, 8 in., and 9·2 in. shell if a number of makers came on to the new design at once.[4] In May and June the supply of fuse and gaine gauges was somewhat in arrears, because contractors were being put on to the new designs of these components before sufficient time had elapsed for gauges to meet the new requirements to be designed and supplied.[5] The shortage, however, was soon made good, and in general the efforts of the Gauge Department prevented any great delay in output. It was inevitable, however, that there should be a considerable amount of waste, both of labour and of finished gauges. The Gauge Department made every effort to reduce waste by anticipating alterations in requirements, and by promptly stopping work on obsolete gauges and having them converted into new designs; *e.g.*, in January, 1916, Messrs. Cotton & Sons were ordered to convert 100 partially finished gauges for 6 in. shell into gauges for 60 pounder shell, and a number of finished gauges were also issued from the National Physical Laboratory for similar conversion.[6]

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[1] D.A.O./2/1244.

[2] Hist. Rec./H/1121-24/6.

[3] (Printed) *Weekly Report*, No. 30 (19 February, 1916), p. 126.

[4] *Ibid.*, No. 39, III. (29 April, 1916).

[5] *Ibid.*, No. 42, III (20 May, 1916); No. 45, III. (10 June, 1916).

[6] 94/G/1551.

Changes in the design of gauges other than those necessary to meet changes in the design of stores had the effect of accelerating production, since their object was always to simplify the work from the gauge manufacturers' point of view. Increased tolerances were sometimes allowed where experience showed that there was a special difficulty in manufacture. Thus in August, 1915, the rejection by the National Physical Laboratory of 50 per cent. of the gauges made for 2 in. trench mortars led to a request for the tolerance to be increased. It was suggested that the gauges might be made to ·001 in., and the Chief Inspector agreed "to do his best to pass the gauges on to Woolwich" with this tolerance.[1] Increased tolerances were also allowed on screw gauges in October, 1915.[2]

In December, 1915, a Committee consisting of manufacturers and representatives of the Ministry was appointed by General Minchin "to deal with and finally determine the best designs of gauges for the purposes required." This Committee originated in a meeting of representatives of the Boards of Management held at the Ministry on November 5 to discuss certain difficulties connected with the supply of munitions. The chief direction in which simplification took place was in the matter of tolerances, the Committee recommending that increases should be allowed in several cases.[3] About 24 February, 1917, a meeting of the Engineering Standards Committee considered the question of the most suitable standards to be adopted for screw-threads, and the gauge contractors to the Ministry were asked to give information as to the most suitable form of thread and the tolerances that should be permitted to gauge-makers.[4]

The Ministry always welcomed any proposals for simplification offered by firms, as, for instance, that of Messrs. Herbert, who, on being asked to tender for gauges for Fuse 84, delayed their quotation in order to take up with the Inspection Department a slight modification in design which would facilitate manufacture and reduce the cost.[5] Gauging devices of different kinds have been invented by many firms to meet needs which have become apparent with the development of new stores. Frequently the introduction of such devices has proved of the greatest value in securing increased accuracy of manufacture or in facilitating rapidity of work.

V. The Testing of Gauges.

Before the war, the testing of gauges for all munitions except rifles took place at Woolwich, where the necessary check gauges were kept. This system was continued until the middle of 1915, when the immensely increased output of all stores, especially gun ammunition and components, made it impossible for Woolwich to cope with the

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[1] T.W./B.M./3406. T.W./2767.

[2] (Printed) *Weekly Report*, No. 13 (23 October, 1915), p. 9

[3] HIST. REC./R/1121/18.

[4] (Printed) *Weekly Report*, No. 81, II. (24 February, 1917).

[5] 94/G/2258.

gauges that came pouring in for testing. When the Ministry of Munitions was formed, new arrangements were made. While some testing still took place at Woolwich, the majority of gauges were diverted to the National Physical Laboratory and tested there. For a few months, while the system of contractors providing their own inspection gauges was in force, some gauges were checked locally, checks being sent from Woolwich when needed ; but when the Gauge Department undertook the supply of all inspection gauges, local checking was no longer necessary, and the work was divided between Woolwich and the National Physical Laboratory, which was in close touch with the Inspection and Supply Departments of the Ministry.[1]

Woolwich continued to deal with gun gauges entirely, and also with gauges for ammunition made by the Ordnance Factories, and for special ammunition only made by two or three contractors. These gauges were to be sent by the makers direct to Woolwich (where the inspection of all special ammunition took place) to be tested and stored there, checks being procured by the Inspection Department from the Royal Laboratory.[2]

All gauges for ammunition in general use, made by a large number of contractors, were sent to the National Physical Laboratory, where they were tested and stored, checks for testing purposes being supplied, whenever possible, by the Gauge Department and kept at the Laboratory. The work which thus fell on the Laboratory was enormous, since the majority of ammunition came into the category of " ammunition in general use." Moreover, as the Department widened its activities to include the supply of gauges for trench warfare ammunition, aircraft, and Admiralty requirements, the testing of these was also put into the hands of the National Physical Laboratory. The organisation of the Laboratory had therefore to be rapidly expanded to meet the demands made upon it. In June, 1915, the staff of the Metrology Department, which dealt with gauges, numbered only five, and the gauges dealt with amounted to about 1,000 a year. Before the end of the year over 50,000 gauges had been tested. This was only rendered possible by a large increase in the staff and appliances. In spite, however, of all the efforts of the staff, the delivery of gauges (at the rate of 600 a day) was in September exceeding the capacity of the Laboratory, and a night shift was put on to deal with the arrears. This, however, was only a temporary expedient, and was discontinued in November, when the congestion was overcome, and the Laboratory settled down to regular work.

During 1916 gauges were being tested at the rate of over 4,000 a week, and this necessitated a further increase of the staff. About February it was decided to experiment with women's labour. This proved very successful as far as the less accurate parts of the work were concerned, and a fair percentage of the staff, which in January, 1918, numbered 200, was composed of women. After the Laboratory took up the increased gauge testing work, the accommodation was

[1] C.R./1250. [2] 94/G/480.

steadily increased, and, besides new buildings for testing, a large new store was erected (July, 1915), in which passed gauges were stocked until they were required by manufacturers.[1] During 1917 the gauges passing through the Laboratory averaged nearly 10,000 a week.

The chief difficulty which the Laboratory experienced was the shortage of check gauges. These were practically unprocurable at first for the new types of inspection gauges. In some cases, *e.g.*, Fuse 100 gauges, the Laboratory made the necessary checks, but for the most part testing was done by direct measurement by means of the standard block gauges made by Messrs. Johansson, of Sweden. Gradually a few firms in England developed the manufacture of check gauges, but the supply was by no means equal to the demand, and much of the testing had to be done by direct measurement.

Most valuable work was done by the Laboratory staff in designing new measuring appliances. This is especially true with regard to the testing of screw gauges. Before the war screw gauges were only being made in England in small quantities by three or four firms, and appliances for testing them were therefore limited. The staff, therefore, turned its energies to inventing new machines, which were then made experimentally in the Laboratory workshops. When the machines were perfected the designs were passed on to specially skilled machine-tool makers, who turned out machines for the Laboratory and also for gauge-making firms. A certain number of the machines required for their own use were still, however, made by the Laboratory staff, and experiments in the production of standard block gauges of the Johansson type were in progress at the end of 1917.

As regards the passing of gauges, the Laboratory experienced the greatest difficulty with screw gauges, and especially profile gauges, or those which test the shape of the thread. At first the numbers sent in were small and the percentage of rejections high. During the last five months of 1915 49·7 per cent. of screw gauges were passed as compared with 75 per cent. of general gauges. A steady improvement, however, took place, both in quantity and quality. In 1916, 64·4 per cent. and in 1917, 68·3 per cent. of screw gauges were passed, while the percentage of general gauges remained fairly steady. The quality of screw gauges, however, improved in a greater ratio than is indicated by these figures, as the rigidity of inspection, due to improved methods of measurement, kept down the percentage of passes.

Besides storing and testing gauges the National Physical Laboratory gave invaluable assistance to the Gauge Department by helping manufacturers to overcome their initial difficulties. Advice as to methods of manufacture was given by the Laboratory staff, and demonstrators were sent out to manufacturers' works if necessary. The Laboratory also arranged to test manufacturers' gauges when desired.[2]

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[1] C.R./971. [2] HIST. REC./R/1121/23.

Rifle gauges did not fall within the purview either of Woolwich or the National Physical Laboratory, being tested and stored at Enfield.

VI. Conclusion.

The partial cessation of the manufacture of munitions which followed the signing of the Armistice was naturally accompanied by a similar curtailment of gauge manufacture. Contractors were notified by the Gauge Department that, generally speaking, orders would cease immediately, and that they would be required to complete outstanding orders or to deliver the unfinished gauges to the N.P.L. as soon as possible. In many cases contracts were concluded by mutual agreement, and in others by the operation of the break clause. Screw gauge manufacturers who had contracts for aeroplane gauges were allowed to continue, as the demands of the Air Department were not considerably affected by the Armistice. As has been said, arrangements were made for the return of the National Gauge Factories to private ownership as soon as possible. It was expected that most of the firms concerned would return to their normal business if that had been interfered with, though possibly both the Vidal Engineering Company and Messrs. Pitters would continue high-class gauge-making.

The developments which took place in gauge manufacture under the direction of the Ministry between 1915 and 1918 will probably have a marked effect on the future of the industry. With the aid of the Gauge Department many firms succeeded in equipping their factories with suitable plant, and organising their industry on a firm basis. The extended use of limit gauges, which has been such a marked feature in the engineering trade during the war, seems likely to continue, and this will create a demand, which will enable these firms to carry on a business thus successfully developed. Very valuable experience has also been gained with regard to the importance of a steady supply of machinery of simplified design, the part that can be played in gauge manufacture by repetition work, and the value of simplicity in design in promoting rapidity of output and economy of production. If the experience thus gained and the organisation built up through the exigencies of war can be utilised in the period of reconstruction following the war, there seems no reason why a flourishing gauge industry should not be established, which will help to absorb the labour released from the Army, and place the supply of gauges, which, before the war, was largely in the hands of foreign countries, under the control of home manufacturers.

CHAPTER II.

MACHINE TOOLS, SMALL TOOLS AND CRANES.

I. Introduction.

The manufacture of machine tools is not, in one sense of the word, a primary industry in relation to war. That is to say, machine tools do not, like guns, shells and explosives, play an immediate part in the field. But in so far as these and all other munitions cannot be produced in the quantities required by modern methods of warfare without the use of highly complicated machinery, machine tool manufacture may be rightly termed a key industry. At the outbreak of war, this fact was not fully recognised either by the workman, who tended to leave the industry for service in the army or for the direct production of war material, or by those responsible for the output of munitions, and no immediate steps were taken to organise the industry for war production. Experience, however, rapidly corrected this mistake. Leaders of the industry were the first to realise the danger of neglect, and drew the attention of the Government to the need for investigating the potentialities of the trade. Once set on foot, the organisation for the control and distribution of machine tools rapidly expanded under pressure of the increasing demand, and during the whole period of the war it formed one of the most important of the Government activities.

(*a*) Definition of Terms.

Machine tools can best be defined in general terms as "power-driven machines for cutting, working, or abrading metal." The original machine tool was the lathe, the modern commercial development of the potter's wheel. The lathe in its different forms is still the principal machine tool used in every industry, but by its side modern invention has placed milling machines, planing, shaping and slotting machines, boring and grinding machines, automatic screw machines and various other tools designed to promote rapid and efficient output. All these machines are made in different forms and sizes according to the use to which they are to be put. For the production of artillery, for marine engineering and shipbuilding, machines of the heaviest description and largest dimensions are necessary; at the other end of the scale there is the light machinery required to make rifles, cycles, sewing machines, watches, optical instruments, and other delicate articles. Between these two extremes lie infinite possibilities as regards size and form, and a definition which is general enough to cover all the varieties of machine tools and yet simple enough to appeal to the non-technical mind is not easy to find.

Wood-working machinery, though closely allied in principle to metal-working machinery, obviously does not fall within the limited definition given above. In attempting to control the machine tool trade it was, however, found that wood-working machinery must be dealt with also. For the immediate purpose, therefore, the scope of the term "machine tool" may be widened to embrace both metal-working and wood-working machinery.

The small tool is so closely connected with the machine tool that one is useless without the other. Different machine tools require different small tools such as chucks, arbors, cutters, drills, reamers, taps, dies, jigs and fixtures, according to the function they have to perform. The small tools, generally speaking, do the actual work of shaping and cutting to the dimensions required, while the machine tool is the medium through which movement and direction are given to the smaller implement. The greater wear and tear thus falls on the small tool and necessitates its frequent replacement. It is therefore necessary to have an adequate supply of small tools with which to equip a machine if it is to be kept working at its maximum capacity, and one of the most obvious lessons driven home by the war was the need of greatly increased facilities for the manufacture of small tools. Although not actually used for cutting, many measuring and gauging appliances are included under the heading of small tools.

Machine tools play an indispensable part in modern industry, for production on any scale at all is impossible without them. The old method of manufacture, in which the individual craftsman worked at an article in all its stages from the rough shape to the finished form, has been replaced by the co-operation of a number of people, each of whom specialises in one operation only on large numbers of articles which are turned out in quantities by repetitive methods. The parts are then assembled to produce the finished article. But in order that the parts may fit one another when assembled they must be accurate within limits extending in many cases to considerably less than a thousandth of an inch. Such accuracy cannot be secured by hand labour without a high degree of skill and a large expenditure of time. A machine tool, on the other hand, can be made to turn out uniform articles to any reasonable limits as long as it is maintained in sound condition. If, therefore, the attention of the skilled workman is concentrated on the production of an accurate machine tool, semi-skilled labour can be used to operate it without detriment to the quality of the article to be produced. The value of machinery in securing rapidity and economy of output is obvious, while its accuracy is such that even the most delicate mechanism, as, for instance, that of the modern rifle, can be produced far more efficiently than by hand labour. In a crisis such as war, output on the scale of war requirements can only be achieved by the intensive use of mechanical devices of every description, and an adequate supply of machine and small tools is therefore a *sine qua non* for military success. Thus it was necessary during the war to pass outside the area of munitions in the strict sense of the word and to organise for war purposes an industry which was already existing as an essential part of our normal industrial organisation

The achievement of the Ministry of Munitions with regard to machine tools was not the creation of a new industry ; it was rather the stimulation and remodelling of an old industry to meet new and abnormal conditions.

(*b*) The Machine Tool Industry at the Outbreak of War.

At the outbreak of war the machine and small tool industry in Great Britain was in the hands of three classes of traders :—(*a*) the manufacturer ; (*b*) the merchant ; (*c*) the importer.

These divisions were not, however, mutually exclusive ; for the development of the industry was tending towards making the merchant also a manufacturer, while the manufacturer often added to his activities the further functions of merchant and importer.

Machine tool manufacture in Great Britain was, broadly speaking, grouped in four districts, where the demand for machine tools was great on account of the industries of which these districts were the centre. Lancashire was the early home of the machine tool trade, and at one time had the reputation of producing the best quality tools. Yorkshire competed closely in quantity of output, but the machinery was, with some exceptions, of a lower grade, being simpler in design and produced by a number of small makers who had not the organisation and the up-to-date methods of the larger trades. The Midlands produced, on the whole, large numbers of machines of the type required for repetition work and suitable for use in the small arms, motor and cycle trades, while the shipbuilding and marine engineering industries of the Clyde had resulted in the development of a flourishing industry in machine tools of the heavier type in the immediate neighbourhood.

With certain outstanding exceptions, the general tendency of the British machine tool maker was conservative both as regards novelty in design and quantity of output. Most machine tool makers built simply to order, each firm producing in small numbers machines of the designs required by its customers. This lack of specialisation, combined with lack of enterprise in building for stock, tended to limit the trade of British machine tool makers, though for strength and durability the British machine tool had a reputation second to none on the market. American competition was, however, steadily eliminating these faults of too great caution and uneconomical methods of production, and immediately before the war makers were developing the methods of specialising in a certain type of machine, and building for stock, and therefore adopting a more active commercial policy abroad as well as at home. Not only did British products hold the field at home as far as certain classes of machinery were concerned, but they were exported to every country in the world except the United States, which had a prohibitive tariff, and they competed with advantage in foreign markets with the productions of America and Germany, the only other countries with a considerable machine tool industry.

The developments in the industry contributed to the growth of the merchant business. The merchant often began as a second-hand machinery dealer ; then he extended his business by acting as middleman for the small maker, often financing him and making it possible for him to increase his manufacture. During the years immediately before the war there was a marked tendency for the merchant to extend his operations to the better types of machinery, while the export trade was largely in his hands. In many cases it was the practice of the merchant to undertake to furnish a large plant for the manufacture of a particular article, procuring the necessary tools from many different makers.

The third class of trader, the importer, played a large part in the organisation of the whole industry. The two principal countries from which machines were imported before the war were America and Germany. Of the two, the former was by far the more important, and as, automatically, importation from Germany ceased on the outbreak of war, America became to all practical purposes our sole source of foreign supply. The American output of machine tools was large owing to the fact that a prohibitive tariff secured to her an enormous home market, while she was also free to enter the markets of other countries. American makers could thus build in large quantities for stock, and this, combined with their specialised and progressive business methods, enabled them to produce cheaply and efficiently in spite of high wages, and to capture the markets of other countries to a large extent. As a rule, American machine tools were imported into the United Kingdom by firms within this country, who established themselves as general American importers. As these firms increased in number they developed a tendency to specialisation. Each firm secured sole agencies for a certain number of American manufacturers, who assisted them by sending trained demonstrators over to work the machines and to advertise their advantages. Immediately before the war, the importing industry formed a large part of the machine tool trade in Great Britain, especially as regards machine tools of the lighter type and small tools, for the supply of which we were in many cases almost entirely dependent on American enterprise.

Thus at the outbreak of war there was a steady supply of machine tools in Great Britain to meet the normal demand, and the tendency was for this supply to increase as new industries developed, and labour-saving machinery usurped the domain of skilled labour. As in most other industries, the effect of the war was to produce a temporary paralysis. The demands of the arsenals, the dockyards, and the armament firms only increased very gradually at first, while other contracts were cancelled, for the financial uncertainty of the early days of war acted as a check on enterprise. Matters, however, adjusted themselves after a month or six weeks, and as the demand for munitions went up by leaps and bounds, the pressure on the machine tool trade became enormous. It became obvious that the existing resources of the trade, hampered as it was by increasing scarcity of labour and material, would not be sufficient to meet the demands unless

much greater output could be secured by improved organisation and proper distribution. The matter was taken up as a question of national importance in the spring of 1915, and the first steps were taken by the Government towards a system of control which eventually became as widely spread and as rigidly enforced as that applied to any other industry in the United Kingdom.[1]

II. Organisation of the Machine Tool Department.

(*a*) Headquarters Organisation.

The first movement towards organisation came from within the trade itself. In March, 1915, Mr. Alfred Herbert, who, as Chairman of the Machine Tool Association (which included in its membership the majority of the leading manufacturers, merchants and importers) and head of one of the largest machine tool firms in the kingdom, had unique opportunities of knowing the state of the trade, wrote to Sir Arthur Lawton, the Chairman of the Engineering Employers' Federation, and to Mr. Lloyd George, then Chancellor of the Exchequer, making suggestions as to how the existing chaos might be straightened out and a better distribution of output secured. The result was that in April Sir Percy Girouard asked Mr. Herbert to undertake the organisation of the machine tool trade. On 27 April the department began operations on a small scale at the Cecil Chambers as a department of the War Office. For about two months it worked thus with very nebulous powers; then, on the establishment of the Ministry of Munitions in June, 1915, it was transferred to Armament Buildings, and systematically organised as part of the Ministry.

It is impossible to describe in detail the organisation at Armament Buildings. There are, however, certain landmarks in the growth of its personnel and functions which can be recorded. At first no differentiation was made between machine and small tools, but as the small tool problem developed it became necessary to deal with it on special lines, and in September, 1915, a Small Tool Section was organised in the department. In March, 1916, the extension of control to lifting and conveying appliances brought into being the Crane Section, while the difficulty in obtaining raw materials resulted in September, 1916, in the establishment of the Stamping and Casting Section. This last appears, however, to have been in the nature of an anomaly within the Machine Tool Department, and was transferred to the Steel Group at the end of 1917.[2] On the other hand, the work of the department was considerably increased by the control of prices, which necessitated the formation of a Prices Section, and by the transference to the department in September, 1918, of the work of the Central Clearing House with regard to the release of machine tools.[3] At the signing of the Armistice the department was organised as a

[1] See History of the Machine Tool Department, Part I., by Sir Alfred Herbert. (Hist. Rec./H/1700/1.)

[2] See below p. 55.

[3] See below p. 45.

complete unit under the Controller, Mr. Edward M. Iliffe, who had succeeded Sir Alfred Herbert in April, 1918, in seven sections (T.M. 1-7), dealing respectively with the supply of machine tools, prices, small tools, cranes, control, investigations and releases. Complete arrangements were also made for the department to take over machine tool stores and accounts from the Central Stores Department, but upon the signing of the Armistice this was abandoned.

The Machine Tool Department was organised at the beginning by voluntary workers, and the men responsible for the direction of its policy throughout the war served, in nearly all cases, entirely without remuneration. Among these may be specially mentioned Sir Alfred Herbert, the first Controller, and Mr. Edward M. Iliffe, who succeeded him, and who was attached to the department for over four years. Mr. P. V. Vernon placed his wide technical experience unreservedly at the disposal of the Ministry, and his services in this respect as well as his administrative work as Assistant Controller proved invaluable to the department. Another valuable voluntary worker was Mr. J. D. Steven, the head of the Small Tool Section. The debt that the Ministry owed to these and other workers was all the greater in that the successful establishment and working of the Machine Tool Department depended largely on the possession of expert knowledge of machine tools and the machine tool trade. In 1915 men with such knowledge could hardly have been secured by ordinary business methods. It was therefore only by voluntary assistance that the department was able to carry on its work, and to keep that close connection and cordial co-operation with the trade in which the secret of its success is very largely to be found.

(*b*) Advisory Committees.

As the increasing activity of the department entailed more and more interference with the trade, it was felt desirable to secure the co-operation and advice of the leading machine tool makers who would act for the whole trade in protecting its legitimate interests and securing its acceptance of the necessary control. The formation of a committee of the trade had been a leading feature of Mr. Herbert's early suggestions, and in July, 1915, the idea was again put forward by Mr. Lloyd George, at a conference with the leading manufacturers, as the best means of administering control. Accordingly a voluntary Advisory Committee of six was appointed by the Minister of Munitions, Government appointment rather than election being the method decided upon by the makers themselves. In addition to the Chairman, Mr. Herbert, there was a representative from each of the four principal manufacturing districts and a representative of the importing firms. Additions were made at intervals during the lifetime of the committee. In September, 1915, the Director of the newly formed Small Tool Section, Mr. J. D. Steven, was elected. In December, 1916, Mr. Iliffe, Assistant Director of the Machine Tool Department, became a member, and two members were added to represent the Finance and Contracts Departments respectively in order to obtain closer co-operation between

the several departments. Early in 1917 a representative of the wood-working machinery trades was elected, and in February, 1918, the Director of the Prices Section, Mr. J. W. Milne, was also appointed to the committee.[1]

In July, 1917, a Sub-Committee was appointed to advise the Machine Tool Committee with regard to applications by individual firms for permission to increase their prices. It consisted of those members of the committee who were not members either of the machine tool or wood-working machinery trades, together with a representative of the Controlled Establishments Division. Mr. Edward M. Iliffe acted as Chairman. Practically all questions relating to prices were dealt with by this sub-committee, whose recommendations were formally confirmed by the Machine Tool Advisory Committee.

In the autumn of 1918 a second advisory committee was constituted, on lines similar to the Machine Tool Committee, to deal with small tools. The limitation of merchants' and importers' profits on small tools during 1917, and the control of manufacturers' prices early in 1918, evoked a general demand for such a committee. The first meeting of the Small Tools Advisory Committee was held in September. It consisted of eight representatives of the small tool trade and six Ministry officials, most of whom were already serving on the Machine Tool Committee.[2] Owing to the signing of the Armistice in November, the actual work done by the committee was comparatively little, but had the war continued there can be little doubt that it would have proved to the department as valuable a link with the small tool makers as the Machine Tool Committee already was with the machine tool trade.

In September, 1918, also, a Merchants' and Importers' Panel was set up, because the merchants and importers felt that their interests were not sufficiently safeguarded by the Machine Tool Advisory Committee. Its personnel consisted of eleven members representing the trade and five Ministry officials representing the Machine Tool and Contracts Departments,[3] and its functions were to advise the department on matters connected with the sale and importation of machine and small tools.

(*c*) Local Organisation.

The increasing control of the trade necessitated a considerable amount of local organisation by the Machine Tool Department, some of which was permanent, some merely temporary to meet special difficulties. The chief permanent organisation was the staff of inspectors and supervisors. The first travelling inspectors were appointed in September, 1915, and as their work was extended and its value proved, their numbers were increased considerably. Their primary object was to accelerate production by advising manufacturers

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[1] Appendix V. [2] *Ibid.* [3] *Ibid.*

in their difficulties, assisting them to obtain supplies of raw material, suggesting simplification of processes, and generally smoothing the path wherever possible. They also advised the department as to available capacity and when deliveries might be expected; they investigated costs and saw that firms complied with the regulations regarding the trade. In the case of most firms visits at intervals were sufficient to ensure this last, but in certain instances where evasion of regulations was deliberate and repeated, it was found necessary to appoint resident supervisors. During 1916 and 1917 supervisors were appointed by the department to at least five firms.[1] The withdrawal of permits to trade was, however, a more common measure with recalcitrant firms.

Temporary local organisation is found in the measures taken to deal with congestion at the ports. In the early days of the Ministry the volume of importation from America was necessarily large and the result was great congestion at the ports, especially Liverpool. The Machine Tool Department soon found that even when the tools ordered arrived in England, they could not be put into use quickly on this account, so an official was appointed to deal with the situation at Liverpool, Manchester, and London. The result of this move was that machines previously delayed at the ports for five or six weeks were put on rail within a few days of their arrival. So successful was the procedure that the services of this official were requisitioned by other departments, his work was extended to include steel and other materials, and increased in this direction to such an extent that it was considered advisable to transfer the work to the Steel Department, and thereafter, as an offshoot of the Machine Tool Department, it ceased to exist.

Another organisation with a similar history was the mission to America of Mr. Searle and Lieut. Lang in the autumn of 1915. Originally sent out by the Machine Tool Department to induce American manufacturers to ship a larger proportion of their output to England, they extended their operations to the direct purchase in the States, through the agency of Messrs. Pierpont Morgan & Co., of large quantities of machine tools (particularly for heavy shell) and to encouraging general engineering firms to take machine tool contracts with the assistance of drawings and designs supplied by British firms. Eventually this mission was absorbed in Sir Ernest Moir's organisation in the United States, and its work for the Machine Tool Department thus became part of a larger whole.

(*d*) Relations with other Departments.

The work of the Machine Tool Department necessarily involved considerable relations with the Supply Departments of the Ministry,

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[1] These firms were Messrs. Haigh, Gruban & Co., Ltd., and Messrs. J. Whiteley and Son, Ltd., March, 1916; Messrs. Ward, Haggas & Smith, Ltd., October, 1916; The Centaur Tool Works, Ltd., and Messrs. J. R. Kelly & Co., Ltd., June, 1917.

whose ability to meet the demands of the War Office depended to a large extent upon a sufficient supply of machine tools to their contracting firms and upon the proper equipment of national factories. It also involved relations with other Government Departments, such as the Admiralty, the Air Board, and the War Office, from whom there came a considerable demand for machine tools. As Sir Alfred Herbert expressed it, the Machine Tool Department was the "servant of all the other Departments," a position in which it was apt to get more kicks than halfpence. Each Supply Department naturally urged its own particular claims to assistance, and as, generally, no definite guidance was forthcoming in this respect, the department had itself to take the responsibility of adjusting rival claims. At a later stage, however, the War Priorities Committee was set up, and a Machine Tool Sub-Committee was formed, under the chairmanship of the Controller of the Machine Tool Department, to perform this onerous duty.

With the Raw Materials Department, the Labour Supply Department and the Priority Department, the Machine Tool Department was always in close touch, in order to assist manufacturers to fulfil their orders as quickly as possible. Relations with the Finance Department were slight compared with those of other departments, since the expedients of giving financial assistance to firms and setting up government factories were never adopted to any great extent. With the Contracts Department also the connection was not at first close, since the department avoided placing direct Ministry contracts as far as possible ; but this policy had to be modified later under pressure of necessity, especially when the limitation of American supplies in 1918 forced the department to open up new sources of supply at home, and to take the responsibility for making good the deficiency. The placing of direct Ministry contracts then became much more common, and the connection with the Contracts Department correspondingly closer. Ultimately the Director of the Prices Section of the Machine Tool Department was also appointed Director of those sections of the Contracts Department (C.E.6 and C.E.7) which dealt with the placing of contracts for machine tools ; and, as has been seen, a representative of the Contracts Department was appointed to act on the different advisory committees of the Machine Tool Department.

With the Central Clearing House[1] the Machine Tool Department naturally worked in close conjunction, since both dealt with the supply and distribution of machine tools. Contractors wishing to order new machine tools applied to the Clearing House authorities for release certificates to enable them to place their orders, while the firms receiving the orders applied to the Machine Tool Department for permission to supply the machinery required. The Central Clearing House also obtained particulars of available second-hand machinery capable of being transferred to firms requiring similar machinery for war

[1] For a full account of the Clearing House system, see Vol. VIII., Part IV., Chapter I.

work, such information being supplied by them to the Machine Tool Department. It was, therefore, absolutely essential that there should be close co-operation between the two departments if friction and delay were to be avoided. In spite of the efforts of both departments, the delay experienced in obtaining machine tools was a ground for increasing complaint by all firms in 1917 and 1918, and ultimately it was decided that the work done by the Clearing House authorities with regard to machine tools was really part of the work of the Machine Tool Department. In September, 1918, the release of machine tools was handed over to the department, and the necessity for its close connection with the Central Clearing House ceased to exist.[1]

III. Work of the Department.

The phrase "control of metal and wood-working machinery" only indicates very broadly the work of the Machine Tool Department. To appreciate to the full its many-sided activity more detail is needed. Since machine and small tools of various kinds are used in practically every industry, the allocation of output among the numerous manufacturers clamouring for tools alone involved a vast amount of work, as well as tact and discrimination; and when the control of prices was added, supervision of private industry became minute in its detail. In addition, all the requirements of Government Departments, including the Supply Departments of the Ministry, were referred to the Machine Tool Department for advice and approval; and much valuable technical advice was given by the experts on the staff of the department. As the practice of arranging assisted contracts found favour, and the number of national factories increased, this side of the department's work grew very rapidly.

The section of the department over which Mr. P. V. Vernon presided undertook a great deal of work in this connection, as well as in connection with the provision of machines for shell manufacture to private contractors, for which at the time no other machinery existed. Boards of Management and contractors would visit the Ministry with the general idea that they were to make shells, but without the vestige of a notion as to how to set about it, and it devolved upon Mr. Vernon and his staff to instruct them in the minutiæ of shell manufacture. A list of operations with the estimated times would be prepared; advice as to suitable machines to perform the operations would be given; cutting speeds gone into; the arrangement of the machinery and the floor space required discussed; and in fact everything possible would be done to facilitate production at the earliest possible moment. At a later date this work was taken over by the

[1] See History of the Machine Tool Department, Part II., by Sir A. Herbert (HIST. REC./H/1700/1); Memorandum on the Constitution and Functions of the Machine Tool Department at November 11, 1918, by Mr. E. M. Iliffe (HIST. REC./R/263/23); Central Clearing House (HIST. REC./R/1710/1 and 1710/2); Minutes of the Machine Tool Advisory Committee, the Merchants and Importers' Advisory Panel and the Small Tool Committee; Deputation of Members of the Machine Tool and Engineering Association (D.D.G.T./921).

Shell Department, but until the latter was fully organised and possessed of a staff capable of undertaking this detail work, it continued to devolve upon the Machine Tool Department. Mr. Vernon's section also performed similar functions in connection with the gun-relining programme, which at the time was a matter of first-class urgency; and Mr. F. E. Bagnall undertook, with marked success, similar duties in regard to the manufacture of other munitions.

Naval and aerial developments also involved the department in greatly increased activity, since the Admiralty required assistance in obtaining machinery to produce mines, mine-sinkers and other devices for submarine warfare; and the demands of the Aircraft Department increased as their programme of construction was extended. Besides manufacturing activity, the department had to supervise the steadily increasing volume of importation, while the necessity of supplying our Allies involved it in questions of export also. The control of lifting machinery, though narrower in its range and less intricate in its problems, required the collection of a large amount of information and the establishment of relations with an increasing number of firms. Difficulties in the supply of material also involved for a time a measure of control over forgings and castings.

Had the department attempted to supply directly all the many requirements of contractors, Government Departments and Allies, it would have been overwhelmed by the mass of demands made upon it; and from the outset, therefore, it adopted the policy of bringing machine tool firms into relation with the contractors or departments requiring supplies, and limiting its functions to advice and approval. It was, however, impossible to carry out this policy rigidly during the whole of the war; and in certain directions, particularly with regard to small tools, and at certain periods when demand was particularly heavy, the department was forced to add to its work by entering into direct contracts both with British and American makers, and by arranging output in government factories or on an assisted contract basis; but such activity was the exception rather than the rule, and in contrast to most departments of the Ministry the amount of direct supply arranged by the Machine Tool Department was comparatively limited.

Another development of the department's work was the distribution of second-hand machinery. The sources of supply were so inadequate to meet the demand that at an early date it became a matter of primary importance to register all idle machines and transfer them to firms requiring them, instead of sanctioning orders for new ones. This side of the department's work was at one period undertaken in conjunction with the Central Clearing House, but was ultimately taken over entirely by the Machine Tool Department. Thus, in 1918 the surveillance of all the machinery at work or in progress of manufacture in the country, together with the control of that coming in or going out, fell within the sphere of the Machine Tool Department, and only the most careful organisation, both locally and at headquarters, enabled the volume of work which this entailed to be dealt with successfully.

(*a*) CONTROL OF BRITISH MANUFACTURERS OF MACHINE TOOLS.

When the Machine Tool Department was set up, there was so little knowledge of the trade at hand that not even a complete list of machine tool builders existed. In March, 1915, a census of machine tools in use in the engineering works throughout the country had been taken by the Factory Inspectors, but, beyond showing that only about 50 per cent. were engaged on government work, this census had proved of no value. The first thing, therefore, which the department did was to make as complete a list as possible of the machine tool firms in the country, with details of their specialities in manufacture. Armed with this and the facts elicited by the Home Office census, the department endeavoured to introduce some sort of order and co-operation into the trade, and to direct the flow of work into channels where manufacturing capacity was immediately available. Under Regulation 8A of the Defence of the Realm Act, giving the Army Council general powers of direction, limitation, and regulation of manufacturers' output, a circular was issued to the trade in May, 1915,[1] directing manufacturers to classify their orders into Class A—British and Allied Government orders and contractors' orders for machinery for munition work; and Class B—orders from neutral countries and non-munition contracts. Preference was always to be given to Class A work. Detailed information was required as to export orders and orders for civil work, and the department used its discretion as to diversion of the work begun for these to other purposes. The question of orders for neutrals was most important, as there was evidence to show that many of the machines under these contracts were destined for German use. By these measures a great deal was done to direct the existing capacity in the country into the right channels, a course which was all the more necessary as the demands of the great armament contractors became more and more urgent, and the setting up of the National Shell Factories entailed a heavy demand for equipment. Some help in meeting this demand was obtained in June by the diversion of a number of machines from intercepted cargoes from the United States to Scandinavia. These were seized, and the greater part of the machinery was distributed for use in the United Kingdom. Such a course, however, could only afford temporary relief, and the real remedy for the evils of delay in output lay in getting as much production as possible from the manufacturers. To this end officials from the department visited all the firms in the country giving advice and assistance in the obtaining of raw materials, indicating order of precedence in the matter of contracts, and generally affording whatever assistance was possible to the harassed and overworked makers.

Such control as was exercised under the Order of May, 1915, was only general, and dependent for its success to a very great extent on the goodwill of the individual manufacturer. When the Machine Tool Department was transferred from the War Office to the Ministry of Munitions, it was decided to institute a more definite system of control. A circular was issued to the trade on 16 July, 1915, stating

[1] Appendix VI.

that henceforward the machine tool trade would be controlled under the Munitions of War Act, and that a committee would shortly be appointed to confer as to the best means of administering control. This was the Machine Tool Advisory Committee, which played such an important part in the whole scheme of control.[1] This was followed by another circular, stating that all orders for machine tools were to be submitted to the department, and no orders were to be accepted without the sanction of the department, unless they were given by certain of the Supply Departments of the Ministry, the Admiralty, or the Army Council.[2] The system of sanctioning thus instituted formed the basis of the whole system of control. By the submission of orders the department gained detailed knowledge of the types of machines required, while by refusing sanction they were able to eliminate civil and commercial work in a systematic fashion and concentrate firms' efforts on machines essential for war work.

A census of orders taken in July, 1915, showed that on an average firms were booked up for the next six months. At the same time the inception of the scheme of National Projectile Factories threw upon the department the responsibility of arranging for the large amount of machinery necessary for their equipment. This brought the department face to face with the problem of extension of output. So far they had been occupied with organising the existing sources of supply in order to gain the maximum output, but it was obvious that existing sources could not possibly meet the new demand. There were four possibilities of extension :—National Machine Tool Factories, similar to the National Shell and Projectile Factories ; assisted contracts on the same lines as those already arranged for shell production ; financial assistance to firms to enable them to undertake extensions ; and sub-contracting. As the policy of the department was not to undertake supply itself except as a last resource, the first two expedients were not adopted, the third was only sparingly used, and the department relied chiefly on the extension of sub-contracting to provide the increased output necessary.[3] Machine tool manufacturers were encouraged to sub-contract to general engineering firms who had available capacity, and to allied industries, such as printing machinery firms, and the department rendered all assistance possible by collecting information as to such facilities and communicating it to the trade, and by sending inspectors and officials to give advice and help to firms undertaking such work when required. Many difficulties of detail inevitably arose from this sub-contracting system, such as the use of drawings and patterns, the question of whether a sub-contractor to a certain manufacturer should be allowed to take work from other manufacturers as well, and whether contractors might legitimately place speculative orders with sub-contractors. The general policy of the department appears to have been to interfere as little as possible between contractor and sub-contractor and to leave the sphere and the activity

[1] See above p. 41.
[2] Appendix VII.
[3] This refers to machine tools only. With regard to small tools, a limited amount of Government activity was necessary (see below p. 52).

of the sub-contractor as free as possible. An inevitable result of the sub-contracting system at first was the inferiority of many of the machines produced, but this defect was remedied to some extent by time and experience. On the whole the sub-contracting method appears to have worked well and was very largely employed during the whole period of the war.

Financial assistance to firms was a second string, but was a policy adopted with considerable caution. In September, 1915, a Birmingham firm asked for financial support in the form of the Government holding of debentures in their firm, and was told that the Machine Tool Committee were unable to recommend the Government to undertake financial responsibility at that date. This policy was generally adhered to throughout the war, though in 1918 the necessity for replacing the dwindling American supplies by home manufactures led to its modification being considered, but not acted upon.

The application to the machine tool trade in August, 1916, of Regulation 30A of the Defence of the Realm Act, which prohibited firms from trading without a permit, was primarily in the interests of price control, and will therefore be dealt with in that connection.[1]

The next tightening of control came early in 1918 when the effect of America's entry into the war began to be felt. The limitation of export which this entailed made it necessary to make good the deficiency by home manufacture. Accordingly the department began to apply systematically a procedure which formerly had been only tentative, the policy of concentrating certain manufacturers on certain types of machines entirely. Manufacturers were asked to submit their manufacturing programmes to the department and these were then adjusted and rearranged. Firms who were best equipped for the production of a standard machine were told to concentrate on those machines. Firms whose programmes showed a dissipation of energy over a variety of different types of machines were instructed to cut down their proposals to a few types in the production of which they had already proved their capability, and all firms were asked not to manufacture any articles other than machine tools if these conflicted with the output of machine tools. This was very necessary, as many machine tool makers were tempted to undertake other work, such as parts for aeroplane engines, which would have enabled them to earn a higher rate of profit than they were allowed to make on machine tools.

The Armistice intervened before the real result of this policy could be seen, but there were indications even at that time that it would have produced a still greater increase in output, and 1919 would have seen the greatest possible use being made of the existing facilities, and the maximum output attainable by organisation without extension being secured.

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[1] See below p. 60.

(*b*) Control of Importation of Machine Tools.

In spite of the increase in home manufacture, importation played a large part in the supply of machine tools throughout the war. Certain types of machines were not manufactured at all in Great Britain, and British industry needed supplementing wherever possible because of the enormous demand. The majority of imported machines came from America. Some were obtained from Spain and Switzerland, but there were such difficulties with the supply of raw materials, all of which had to be sent from Great Britain, and so much delay in delivery that little reliance could be placed on these sources of supply. Moreover the prices were quite uncommercial and almost prohibitive. From America there was a steady flow of machinery into the country, in spite of the transit difficulties experienced. Besides the temporary congestion at the ports, due to the sudden activity of the importers following the outbreak of war, there was the possibility of the destruction of large consignments of tools by enemy action at sea. This was brought home very forcibly to the authorities by the sinking of s.s. "Cymric" with 1,387 cases of machine tools on board. Such disasters were, fortunately, comparatively few, and once the initial difficulties were surmounted, the system worked as satisfactorily as could be expected in view of the increasing requirements for the transit of all kinds of munitions and the decreasing number of ships available.

The acceleration in demand owing to the establishment of the National Projectile Factories led to attempts to get a larger proportion of American machinery exported to Great Britain, and then to get an expanded output in the States. The principle adopted at home of encouraging general engineering firms to undertake the work was applied in the States through the agency of Mr. Searle and Lieut. Lang.[1] In this lay the only possibility of expansion, since in the autumn of 1915 American machine tool firms were overwhelmed with orders, and were in addition involved in labour difficulties. The success of the policy may be judged from the fact that orders to the extent of £1,000,000 were placed through Messrs. J. P. Morgan; but there must also be reckoned the very considerable drawbacks in the relative inferiority of many of the machines, both in materials and workmanship, as well as the uncertainty of delivery. The former defects were to some extent overcome by the organisation of a system of inspection in the States. To deal with the latter, cancellation clauses were inserted in the contracts; but it was not often necessary to put them into force, since the demand was so great that, however late in delivery, a use could be found for the machines.

In November, 1915, a Proclamation was issued prohibiting the importation of machine tools except under licence of the Board of Trade.[2] Like the permit system with regard to manufacture, this was designed to control prices, not to limit supply. Limitation of importation became, however, inevitable in the autumn of 1917

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[1] See above p. 43.

[2] Appendix VIII.

because of America's own needs. In February, 1918, the Minister stated that it was advisable to reduce the importation of American machines to the absolute minimum. Arrangements for the manufacture at home of machines hitherto imported were made by the department, but the difficulties in the way were considerable, since the regular machine tool firms were already fully occupied, and the novelty of many of the designs required made less experienced firms chary of undertaking the work. Judging by the figures of importation for 1918,[1] which show no appreciable decrease during the year, the effect of any arrangements made were not felt before the signing of the Armistice. Probably, however, they would have resulted in a considerable alteration in the proportion of imported supply to home manufacture during 1919.

(*c*) CONTROL OF WOOD-WORKING MACHINERY.

The control of wood-working machinery was not imposed till comparatively late in point of time. In May, 1917, owing to the growing demand for machinery for aeroplane construction and to the fact that controlled machine tool firms were penalised as against uncontrolled wood-working machinery firms, there arose a strong demand for the extension of control to include wood-working machinery. The result was that in June an order was issued placing such machinery under Regulation 30A of the Defence of the Realm Act.[2] The system of permits to manufacturers and licences for importation, together with their correlative, the control of prices, was thus extended to wood-working machinery.

(*d*) CONTROL OF SMALL TOOLS.

The problem of the supply of small tools was one of the earliest the department had to face, and it was complicated by the fact that the number of small tool makers in the United Kingdom was comparatively limited, while the demand was relatively large owing to the wear and tear to which small tools were subjected. The first step taken by the Small Tool Section, over which Mr. J. D. Steven ably presided, was the formation of a list of small tool manufacturers with particulars of their output. This was then compared with the information as to requirements obtained from the largest users, including various Government Departments. The result showed there was likely to be a considerable shortage. Steps were immediately taken to induce firms to make extensions to their works, and 19 firms, principally in the Birmingham, Sheffield, and Manchester areas responded to the appeal.

This expedient, however, proved insufficient as soon as the demands of the national factories began to pour in. The department therefore went outside the small tool trade and assisted firms who were willing to undertake the manufacture of special tools and fixtures.

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[1] Appendix XII. [2] Appendix X.

Though no general control of the small tool trade was instituted till a comparatively late date, control of certain supplies which presented particular difficulty began in 1916, and it was in connection with these that Government enterprise was undertaken. Spade-cutters, chucks and taps all required special measures to obtain the increased output necessary, and, contrary to the procedure adopted in the matter of machine tools, the Ministry obtained control of special factories for this purpose.

National Tool Factory, Gateshead.—The most important of these was the National Tool Factory at Gateshead-on-Tyne for the manufacture of spade-cutters. In May, 1916, a disused building was rented for £120 a year from the Lumsden Machine Tool Company, and equipped with plant at an initial capital outlay of £7,000. New buildings were added towards the end of 1917, and the capital cost rose to £18,327 by October, 1918, but, compared with a monthly turnover of £12,000 in 1918, this was not an unreasonable amount. The whole of the money required for the establishment and the carrying on of the factory was supplied by the Ministry.

Production began in August, 1916, and by the end of the year the estimated output of 3,000 cutters a week was obtained. After the extensions, the remaking of cutters and the reclaiming from scrap of high speed steel which was reworked into smaller cutters was undertaken, and the output was raised to 5,000 a week, a supply adequate to meet all requirements.

The management of the factory was in the hands of Mr. Lumsden, of the Lumsden Machine Tool Company. He was appointed by the Ministry, and carried on the factory on most economical and up-to-date methods. It had been the intention of the department to carry on the factory on purely commercial lines, selling the product at the average market price. Under Mr. Lumsden's management it was found that the market price could be halved and still leave a considerable margin of profit. This result was obtained by standardisation of the cutter, by the use of special machines of Mr. Lumsden's own design, by the utilisation of scrap metal, and by the large use made of unskilled labour. In October, 1918, 95 per cent. of the labour at work in the factory was unskilled, and 70 per cent. of this was women's labour. The decrease in the cost of the cutter produced in the factory had the effect of lowering the prices of private firms who continued to produce spade-cutters, and was, moreover, reflected in the lessened cost of producing shell. In 1916 the spade-cutter cost approximately a shilling a shell bored, taking 6-in. shell as a basis. At the end of 1918 it was under a penny a shell bored, in spite of the increased cost of labour and material. This reduction was due not only to the decreased cost of the cutter, but also to the fact that the life of each cutter was very considerably lengthened by improvements in design and in the hardening process.

The Coats Machine Tool Company.—The output of the Coats Machine Tool Company consisted of tools of all kinds, including jigs, dies, boring bars, rifling heads and special reamers. It was taken

over by the Ministry, as the management was not considered satisfactory, and the output was poor both in quality and quantity. Originally a branch of a German firm, it had been transformed at the outbreak of war into an independent business under its former manager (Mr. Kotz), from whom it was taken over by the Ministry under the Defence of the Realm Regulations. It was placed under a manager appointed by the department, and financed by the Government as regards current expenses. This resulted in considerably improved output; and at the conclusion of the war the Ministry was able to show a satisfactory profit during the period of its control.

Messrs. Pratt & Co.'s Assisted Contract.—The supply of chucks early became a difficulty, and control of supply and distribution was instituted in May, 1916. This measure proving inadequate, it was supplemented by an arrangement with Messrs. Pratt & Co., of Halifax, to build a factory for producing chucks, towards the capital cost of which the Ministry advanced £20,000. The factory was begun in the latter part of 1916, and by May, 1917, it was delivering regular weekly supplies.

Birmingham Tap and Die Store.—A different method was adopted in dealing with the supply of taps. Control was instituted as early as 1916, but no special arrangements were then made to extend the sources of supply, though running contracts were given to existing makers. Later, owing to the enormous demands of the Air Board, a number of firms were persuaded to undertake the manufacture of taps and dies who had not previously made this class of tool. For instance, a firm making collar studs and buttons changed over completely to taps and dies, and gave large regular weekly deliveries with a percentage of rejections considerably below the average. A special store was opened at Birmingham to undertake the work of inspection and to sell the tools after they had passed inspection. These arrangements proved adequate to keep up a continuous supply of taps, and no further difficulty was experienced.

Grinding wheels and ball bearings were also controlled in 1916, in June and October respectively. As the supply of ball bearings presented special difficulties, it was shortly afterwards removed from the province of the Small Tool Section, and its history will therefore be dealt with separately. The home supply of grinding wheels was improved by the extension of manufacturers' works, but no direct Government enterprise was set on foot. A great deal of reliance was placed on importation in this respect, the supply of grinding wheels having been almost entirely in American hands before the war.

General control of small tools did not begin until September, 1917, when a start was made with imported tools by instituting a licence under the Board of Trade. In December a measure of control of merchants was added and in February, 1918, a demand for the control of small tools arose within the trade itself. This resulted in the Small Tools Order of May, 1918, applying the permit system to small tool firms from 1 June, 1918.[1] Owing to the short time the system was in

[1] Appendix XI.

operation its effect cannot be as clearly seen as in the case of machine tools.

The policy with regard to importation of small tools followed the lines of that of machine tools. The proportion of imported small tools to those of home manufacture was, however, greater than in the case of machine tools owing to the superior position that America had established in this respect before the war. The efforts made to increase the home manufacture tended to correct this, and the figures of the home output show how much was achieved in this respect. In December, 1915, the value of the monthly output from all makers was £78,295 ; in November, 1916, it was £174,895, an increase of over 123 per cent. Figures for the years 1917 and 1918 do not appear to be available. Though part of this increase was undoubtedly due to the increase in the cost of labour and material, the greater part of it can be rightly attributed to the actual increase in output.

(*e*) Control of Cranes and Lifting Machinery.

In March, 1916, a section of the Machine Tool Department was instituted under the control of Mr. T. Evan Davies, whose work proved invaluable, to deal with cranes and other kinds of lifting and conveying machinery. The problem here was the same as that facing the department with regard to other kinds of machinery—the adjustment of an insufficient supply to meet an ever-increasing demand—and the means adopted to deal with it were, broadly speaking, the same. All orders for lifting machinery had to be submitted to the department and permits and priority classification were given to those allowed to proceed. Thus the first step in all control was taken—the elimination of work not strictly necessary for the conduct of the war. Monthly progress reports and notification of the completion of orders had also to be sent in by every firm controlled by the department.

As these measures did not entirely solve the problem, the control of second-hand machinery was taken over towards the end of 1916. Information was required from all in possession of lifting machinery which was not being used, and from this a register was compiled which proved of great value in dealing with the distribution of cranes for war purposes. Permits were necessary for the sale of second-hand machinery similar to those issued for new machinery.

No government factories were established for the purpose of enlarging the supply of lifting machinery, as the close control of distribution succeeded in co-ordinating supply and demand fairly successfully. Neither was any control of prices found to be necessary. The Crane Section, like the other sections of the Machine Tool Department, avoided, wherever possible, the direct placing of contracts, but a certain number were placed in connection with machinery for the Russian Government in 1916.

The number of firms coming under the control of the Crane Section was about 210, and the value of the work controlled was, in 1917, £7,000,000 to £8,000,000 a year.

(*f*) Work in Relation to Stampings and Castings.

The direction by the Machine Tool Department of the supply of drop forgings and malleable iron and small steel castings forms an admirable example of the *ad hoc* character of much of the department's work. Though forgings and castings are closely allied to raw materials, the Machine Tool Department took up the question because one of the obstacles to the supply of machine tools was found to be the lack of adequate supplies of forgings and castings, which are the rough shapes of metal from which all machinery is manufactured. The work of the Stampings and Castings Section, for which Mr. R. M. Atkinson was responsible, was to organise and increase the production of the stamping and casting trades, as well as to co-ordinate supply and demand. The preliminary step of obtaining information as to supplies and demands disclosed a grave shortage of drop forgings for almost all war purposes, and a serious deficiency of small steel castings for aeroplane and motor transport work. Malleable iron castings were in a considerably better position, but in all the trades a lack of organisation was found which resulted in inferiority in quality as well as paucity of output. Accordingly, the section instituted the usual measures to control output, arranging the relative urgency of work and the proportion of civil to munition work which could be allowed. In order to improve the quality of the output, an interchange of visits between the different firms was encouraged, specialisation of manufacturers in certain directions was instituted, and improvements in processes, as, for example, the adoption of heat treatment plants and the substitution of friction lifters for hand-lifted stamps, were established. With the approval and assistance of the department many firms extended their works and their plant, though no direct Government activity was set on foot except in the case of malleable iron castings. With regard to these it was proposed that research should be undertaken in order to improve the methods employed in castings and to conserve the supplies of hæmatite iron, of which there was a considerable shortage. A small foundry at Brentford was taken over under the Defence of the Realm Act for this purpose with its manager and staff, and an analytical metallurgist was appointed by the Ministry.

As the work of the Stampings and Castings Section developed, it became obvious that it was growing beyond the scope of the Machine Tool Department. Forgings and castings are necessary not only for machinery, but for almost all munitions, and therefore they needed to be dealt with by a department with a greater opportunity for co-ordinating and regulating requirements. With this object in view, the control of stampings and castings was transferred to the Steel Group at the end of 1917, and this section of the department ceased to exist.

(*g*) Equipment of National Factories.

One of the most important aspects of the department's work was the assistance it rendered in equipping government factories. The establishment of so many new factories for munitions of all descriptions

entailed a heavy demand for new machinery, which could only be met by careful organisation. At first the department was not consulted at all about contracts for machinery for the National Shell Factories, orders being placed wherever machinery could be obtained and at practically whatever prices contractors chose to demand. But the chaos and extravagance resulting from this procedure soon led to an alteration. From the autumn of 1915 all orders for machinery for National Shell and Projectile Factories were placed only after consultation with the Machine Tool Department, which was thus enabled to allocate capacity to the best advantage and to keep a check on prices. The general policy of the department was to act as technical adviser to the National Factory and as a *via media* between the management and the contracting firm, taking no direct responsibility for the placing of contracts, except as regards the approval of prices. But this procedure had to be modified later on, the department itself placing orders for most of the national factories. In order to decentralise and hasten the work, resident inspectors were appointed to most of the National Projectile Factories in May, 1916.

The equipment of the national factories established during the latter part of the year presented a somewhat easier problem, because there was by this time in existence a large stock of government-owned machinery, which could always be traced through the agency of the Central Clearing House. A certain amount of the equipment of new factories could thus be effected by transference of machines from factories where they were no longer required owing to a change in the type of work being dealt with, and thus the sudden heavy demand which the entire equipment of a new factory entailed was to some extent lessened and a considerable saving was effected.

(*h*) Extended Gun Programmes.

In March, 1917, a very urgent demand came to the department for machine tools for the repair and relining of field guns. This demand necessitated the turning over of several large shell plants to gun repair and later on to gun manufacture. Machine tools for shells were naturally unsuitable for guns, but in view of the urgency of the change it was decided to adapt large numbers of shell machines for gun work. The alterations were extensive, and were mainly carried out by the factories with the advice and assistance of the Machine Tool Department. For the large number of new machines required, specifications were prepared and orders placed by the department. Many of the large machines were split up into units, which were manufactured by a number of firms and assembled into the complete machine by the parent firm. The work of organising this supply was considerable, and the difficulties of inspection great, as many of the firms were new to the work, but it was all successfully accomplished in good time. To carry out the work the department originated several new machines; for example, radial shapers for breech rings, which performed mechanically work previously done by hand, and combing machines for gun tubes.

(*i*) SUPPLIES TO ALLIES.

A problem which faced the Machine Tool Department throughout its whole existence was that of meeting the demands of our Allies. Their plight was even worse than our own, since their industry was not developed to the extent of ours, and they had been in time of peace large importers of German machines. Yet with an output insufficient to meet our own requirements, it was impossible for us to do more than supply a proportion of their needs. Even that was not always possible. In August, 1915, instructions were given by the Minister that all supplies of machine tools to the Allies were to be stopped till the war demands in this country were satisfied. This drastic order was moderated as the situation at home became less difficult, and supplies were resumed. But no general policy was laid down, at all events in the earlier days of the Ministry, and in practice the department was left to gauge the position for itself, and to reconcile conflicting demands, acting on the general idea that British requirements must have primary consideration, but that the demands of the Allies must also be met to the greatest extent possible.

In order to keep a strict control over the export of tools, it was decided in March, 1916, that no machine tools for the Allies were to be authorised by the department unless previously approved by the Commission Internationale de Ravitaillement. Machinery for Russia was, however, an exception to this procedure, all orders for Russian requirements being placed by the Russian Government Commission in co-operation with the Machine Tool Department. The requirements of Russia in the earlier part of the war accounted for the greater number of machine tools exported. Owing to political developments, exports to Russia declined during 1917, and the demands of France and Italy became the chief preoccupation. In March, 1918, the situation in England was such that export for the Allies had once more to be seriously curtailed, and this close restriction continued until the date of the Armistice, when the regulations governing export were modified as a preliminary to their total withdrawal in December, 1918.

In spite, however, of restrictions, the supply of general machinery for the Allies amounted to no inconsiderable sum in value. In 1917 the applications of the Commission Internationale de Ravitaillement dealt with by the Machine Tool Department amounted to about £10,000,000; and the value of tools undelivered at the date of the Armistice was £453,697, France and Italy between them accounting for nearly three-fourths of this amount.

(*j*) OUTPUT.

Figures of sanctions and deliveries do not seem to be available before June, 1916, and then are incomplete, as far as they have been found. The indications are, however, that the value of machine tools sanctioned between June, 1916, and November, 1918, remained fairly steady. For the last seven months of 1916, the average monthly

value was £1,118,170. During 1917 it appears as £1,060,398[1]; in 1918 it rose again slightly to £1,101,712 for the ten months, January to October. This is what would be expected, since in 1916 the demand for new equipment was particularly heavy, and in 1918 the falling off in American supplies necessitated increased output at home. The upward trend of the figures from July, 1918, indicates a much increased programme of British manufacture. As regards the total amount of machinery required, the figures are misleading, since they take no account of transference of machinery, which increased steadily during 1917 and 1918. It appears, therefore, that the total demand for machinery rose steadily throughout the war, and was appreciably higher in 1918 than in 1916.

The figures of sanctions give some indication as to the relative balance of demand from various industries at different periods. The largest demand came steadily from the munition industries co-ordinated under the Ministry, but demands from other sources fluctuated considerably. In 1916 sanctions for the Allies came next in value, being about 30 per cent. of the whole; in 1917 they fell to a comparatively small amount, but rose again towards the latter part of 1918. The figures for aeroplane construction are interesting as showing the rising urgency of this supply. In 1916 the sanctions for War Office and Admiralty aeroplane requirements combined were smaller than those for the Allies; in October, 1917, they had risen to a total almost equalling that of the sanctions for Ministry of Munitions contracts. At the beginning of 1918 aeroplane sanctions were included in those for the Ministry and the Admiralty respectively, and the result was a marked increase in the sanctions for both departments. The value of the Admiralty sanctions in October, 1917, was £35,922; in January, 1918, it was £109,678. Similarly, Ministry sanctions rose from £63,532 to £100,561. Though this cannot be attributed entirely to the demand for aeroplane construction, the greater part of the increase undoubtedly comes from that source, which continued to appropriate a large part of supply during 1918. Admiralty demands were always fairly high, showing a tendency to increase largely in 1917, when machinery was urgently required for the construction of mine-sinkers and other naval devices. The sanctions for the War Office remained small throughout.

Figures of deliveries are available only for 1918. The average monthly value of the deliveries for January to October was £863,586.[2] The actual delivery figures for each month fluctuate considerably, and there is no indication of increased delivery to correspond with the increased programme. But this could hardly be expected, since delivery on sanctions given in the latter months of 1918 would not appear to any appreciable extent till 1919. It is practically impossible to compare sanctions and deliveries except over large periods of time. Broadly speaking, the deliveries for 1918 correspond

[1] This is for nine months only, the figures for July to September being missing.

[2] Appendix XII.

more nearly with the sanctions of 1917 than of 1918, and in so far as any conclusion can be drawn from such rough data, the balance of supply and demand appears to have been very fairly attained in 1918, considering the increasing scarcity of labour and the general difficulties attending the supply of all munitions.[1]

IV. Price Control.

The control of prices formed one of the most onerous duties of the Machine Tool Department. It was an extremely difficult one, because not only was each firm making tools of its own design, which differed from similar classes of machines made by its competitors, but also in pre-war days makers had devoted themselves to the production of machine tools of different grades and qualities; and the prices established on these lines represented the quality of their manufactures as appraised by buyers in the open markets of the world. Regulation of prices was therefore a very delicate matter, and in this respect the advice and co-operation of the Machine Tool Advisory Committee proved of the utmost value. Representing as they did some of the largest machine tool firms in the country, the members, by submitting their own business to control, gave the rest of the trade a guarantee of good faith, while their knowledge of the conditions of manufacture enabled the department to impose general price regulations which would not discourage manufacture, and which would allow as much consideration as possible for individual interests. Control was most rigidly applied to machine tools and wood-working machinery. Small tools were on a much more flexible basis, while cranes and stampings and castings were not controlled by any direct order, though the prices charged by manufacturers were from time to time investigated. The limitations enforced on the machine tool trade applied not only to tools sold for use in this country, but also to those exported to allied countries and to the colonies, as far as existing agreements between manufacturers and their foreign agents permitted.

(*a*) Machine Tools and Wood-working Machinery.

Price regulations differed according to the class of trader, whether he were manufacturer, merchant or importer. The question of makers' prices first occupied the attention of the Machine Tool Department. Between August, 1914, and July, 1915, prices, left to themselves, had risen very considerably, and it was felt that an

[1] See History of the Machine Tool Department, Part II. by Sir A. Herbert (Hist. Rec./H/1700/1); Notes by Mr. P. V. Vernon on work of T.M.2 (Hist. Rec./H/1700/2); Notes by Mr. Atkinson on work of T.M.5 (Hist. Rec./H/1700/3); Notes by Mr. Steven on work of T.M.3 (Hist. Rec./H/1700/5); Replies of Machine Tool Department to Questionnaire of Reconstruction Committee, April, 1917 (Hist. Rec./R/1700/11); Papers relating to Machine Tools (Hist. Rec./R/1700/32); National Small Tool Factory, Gateshead, (D.D.G.(T)/2528); Minutes of the Machine Tool Committee; *Review of Munitions Programme*, September, 1917; Output Tables, 1918, D.M.R.S.

attempt must be made to keep them within reasonable limits. At this date the department had no definite power to enforce price regulations, and therefore any limitations in this direction could only be carried out with the consent of the trade.

On 29 July a circular was issued, asking makers to undertake voluntarily not to make any increases in their prices above those quoted on 1 July, 1915, without the consent of the Minister. The members of the Machine Tool Committee, on the part of their firms, took the lead in agreeing to this proposition, and their example was followed by the majority of the firms in the trade. This does not mean, however, that prices did not increase; it only means that increases were made, for the most part, with the knowledge and consent of the Machine Tool Department. Applications for increased prices were dealt with in detail by the permanent staff of the department under the guidance of those members of the committee who were not members of the trade, as it was undesirable that information as to their competitors' profits should be gained by certain manufacturers through their official position. When an application was sent in details were required as to the costs of labour and materials as compared with pre-war cost. This was then set against the price ruling on 1 July as compared with pre-war prices, and on the evidence of this applications were either granted or refused.

This system depended entirely on the willingness of the manufacturer to submit his prices to the control of the department; if he did not choose to do so, he was perfectly free to make any profit he could from the extraordinary pressure of demand. In order to check this practice on the part of a few firms, the earliest opportunity was taken to place price control on a compulsory basis. The application to machine tools of Regulation 30A of the Defence of the Realm Act in August, 1916, permitted their sale on conditions,[1] and one of the conditions embodied in the permit was limitation of prices according to the rules laid down by the Ministry. Firms who had not been limiting their prices were required to credit their customers with any over-charges they had made since 1 July, 1915, before they were granted permits.

At this period the applications for increases in price became very numerous, owing to the cumulative effect of the steady rise in the cost of material and labour. The investigation into the particulars of individual firms thus became a great tax on the department and the committee, as well as entailing a great deal of extra work on the part of the already overworked manufacturer; and it was felt that it would be an advantage if a simpler system could be adopted. Being now controlled establishments, the machine tool firms came within the scope of the Munitions Levy, and this effectually prevented them from benefiting by charging high prices. Therefore the *raison d'être* for close investigation no longer existed. Moreover, for the purpose of the Munitions Levy, the Controlled Establishments Section now had in its possession information which was substantially the

[1] Appendix IX.

same as that being supplied by the firms directly to the Machine Tool Department. The old system of detailed information and investigation was therefore abolished. Manufacturers were asked simply to give a written assurance that increases, if sanctioned, would not result in a higher percentage of profit on turnover than was obtainable during their standard period, and this assurance was checked by the information of the Controlled Establishments Section. If this profit had been below 10 per cent. prices were sanctioned which would allow a profit of 10 per cent. This was the general system adopted after August, 1916, modified, however, by other factors. Quality of workmanship was taken into consideration, and the position of manufacturers who had to quote for delivery a long time ahead. In such cases firms were allowed to increase their prices by 5 per cent. more than the increases that would have been allowed were the revised prices to take effect immediately.

In January, 1917, the Munitions Levy was abandoned, and controlled owners became subject only to the Excess Profits Duty. The control of prices by the Ministry therefore assumed considerable importance, since a manufacturer was now allowed to retain a percentage of his excess profits whether they were derived from increased output or increased prices. An incentive was thus given to increase prices, and it became necessary to examine price applications with greater care again. To meet this difficulty, the Prices Sub-Committee was instituted in June, 1917.[1] One of its first actions was to advise an alteration in the basis of profit allowed. Owing to the great inflation of selling values which took place in 1917, the pre-war percentage of profit on turnover was thought to be no longer justifiable. The sub-committee recommended that in future the Ministry should reduce the firm's turnover in selling values for the last financial year by 50 per cent. of the amount by which it had been inflated by increases over pre-war selling prices, and fix prices which would allow the firm to make its pre-war percentage of profit on this reduced turnover. This recommendation was adopted and acted upon by the department.

The periodical increases in wages, which became more and more frequent from the summer of 1917, resulted in a rush of applications on these grounds whenever a wage award was announced. It was, therefore, suggested that an automatic increase in prices should be allowed to firms on the approved list to meet this particular difficulty, and in October, 1917, the principle was adopted. It was not applied, however, for every wage increase, since some of these would not have uniform effects throughout the trade. Automatic increases followed the awards taking effect on 1 December, 1917, 1 August, 1918, and 17 December, 1918. On the other hand, it was not considered that the $12\frac{1}{2}$ per cent. increase to skilled men given in November, 1917, and the $7\frac{1}{2}$ per cent. on piece-work of January, 1918, justified automatic increases, and each application was dealt with on its merits.

With the encouragement of sub-contracting to obtain increased output, the question of the exploitation of the sub-contractor came

[1] See above p. 42.

before the department. Machine tool manufacturers were first asked voluntarily to limit their profit on sub-contracted machines to a certain percentage of the actual price paid to the sub-contractor. When the contractor supplied drawings and patterns and supervised the work this percentage was to be 10 per cent.; if working drawings only were supplied, it was to be limited to 5 per cent. In cases, however, when only a few machines were sub-contracted, a margin of 15 per cent. gross profit on cost was allowed if all services were performed by the contractors and the number of machines was three or less, 12½ per cent. if the number was six or less. This arrangement took effect from 17 August, 1915, and continued on a voluntary basis till 28 August, 1916, when it was embodied in conditions of the permit under Regulation 30A. Thus it became obligatory on contractors, and those who had not conformed previously had to give rebates from 17 August, 1915.

The close control of merchants' prices was even more important than that of manufacturers, for merchants were not subject to the Munitions Levy, but only to Excess Profits Duty. That it was necessary may be judged from the following instance. The maker of a certain 6½-in. lathe charged £35 16s. to the merchant who bought it. He sold it at £62 to a second merchant, who passed it on at £66 to a third. This merchant again sold it to another merchant for £70, and he sold it to the user at £87 15s. Thus between maker and user there intervened four middlemen, and the price was increased during the process by £51 19s.

Like manufacturers, merchants first agreed to limit their prices voluntarily. A conference between representatives of the merchants and the Machine Tool Committee was held on 18 August, 1915; and it was agreed that merchants should not increase the existing rate of gross profit, and that in no case should the price to the user exceed 10 per cent. upon the maker's price, no matter how many merchants intervened between maker and user. These conditions were to apply to all orders taken by merchants after 17 August, 1915, but were not to include small tools or individual articles of a value of £10 or less. Neither did they apply to the sale of second-hand machines.

When Regulation 30A was applied to machine tools, this agreement was incorporated as one of the conditions of a permit to sell. The limitations therefore became compulsory, and merchants who had refused to abide by the agreement were required to rectify their transactions as from 17 August, 1915.

The prices of second-hand machines were limited from 28 June, 1916, when a regulation was issued that they should not exceed 80 per cent. of the current market price for new tools of the same type. Thus, though no maximum percentage of profit was laid down, the sale price of such machines was effectively controlled at a time when the supply fell considerably short of the demand. In September, 1918, it was proposed to revise the regulations, and definitely restrict the merchants' profit on second-hand machines to 20 per cent. This was approved by the Merchants and Importers' Advisory Panel, but owing to the improved military situation, and subsequently to the Armistice, the regulation was not put into force.

In November, 1917, an application was made to the department by representative merchants that a higher percentage of profit on new tools should be sanctioned, because working expenses had increased and the volume of business had decreased, owing largely to the Ministry's policy of arranging supply directly with the manufacturer whenever possible. Detailed information as to the position of these merchants' business did not appear to warrant an increase, and as they were not supported by the production of information by the general body of merchants the matter was dropped. In March, 1918, the question was again brought forward, but the Machine Tool Department felt that the information at their disposal did not justify any action being taken at that time, and with this view the Advisory Committee concurred. When the question was once more raised in October, the signing of the Armistice made action unnecessary.

As regards imported machines, the immediate effect of the outbreak of war was a great inflation of prices. The sudden increase in demand made it easy for importers to fix prices which allowed a considerably higher percentage of profit than was customary before the war. Moreover, the business attracted a large number of speculators who had not previously undertaken the importation of machine tools, and who were prepared to offer high prices to the American manufacturers. Thus there was the temptation for the manufacturer to sell to the highest bidder, and prices were artificially forced up.

This state of affairs was ended by the Proclamation of 30 November, 1915, prohibiting the importation of machine tools without licence from the Board of Trade. Licences were only issued to those firms who had been engaged in importing to a considerable extent before the war, or who acted as sole agents to manufacturers abroad, and price regulations were incorporated in the licence as one of the conditions of its issue. In the issuing of licences the Board of Trade acted solely upon the advice of the Machine Tool Department, with whom the responsibility rested.

In order to ascertain what might be considered a fair proportion of gross profit for importers the books of five representative firms were examined and on their evidence $18\frac{1}{2}$ per cent. on the c.i.f. costs at the British port was the amount of profit fixed. This was the average percentage of gross profit before the war. This rate of profit was reduced in February, 1917, to $12\frac{1}{2}$ per cent. on the f.o.b. cost of a machine tool where the cost was £40 or more, and $18\frac{1}{2}$ per cent. on the f.o.b. cost where it was under £40 and over £10. In March and October, 1918, as a result of the decreasing importation from America, applications were made for the profit to be raised to $18\frac{1}{2}$ per cent. irrespective of value, but on the evidence available it was not considered that such an increase would be justified. In December, as a result of the Armistice, all restrictions on the sale of imported machine tools were withdrawn, though a certain measure of price control over small tools was still exercised by the Board of Trade.

These regulations applied to second-hand as well as to new tools. Later the regulation referred to above limiting the maximum prices of second-hand tools to 80 per cent. of the price charged for a new machine, was applied to imported machines. This double regulation had the effect of discouraging the purchase of second-hand machine tools at high prices in America.

Special terms were given by certain importers for machines for National Projectile Factories. They agreed to supply the machine tools of American makers for whom they were sole agents in this country at a profit of $2\frac{1}{2}$ per cent. only on the net cost of the machines as delivered at the factory, a percentage which would probably not even cover the cost to the firms of arranging for the supply. The approximate value of the orders placed on this $2\frac{1}{2}$ per cent. basis was £143,500.

(*b*) Small Tools.

The question of controlling prices in the small tool industry did not arise till January, 1917, and then, in view of the fact that all the larger firms were controlled establishments, it was not felt necessary to lay down definite regulations to govern prices. Manufacturers were told that they must keep their prices within reasonable limits and the percentage of profit on turnover should not be higher than in their two pre-war years.

The first definite step towards control was taken in September, 1917, when the Ministry decided to control the importation of small tools under licence of the Board of Trade, in the same way as machine tools were already controlled. The profit on imported small tools was to be 25 per cent. on the cost at the importer's warehouse. It was found on examination that this would entail hardship on small retail dealers, and in such cases an increased profit was allowed, provided the price to the user did not exceed 35 per cent. of the cost at the warehouse. This arrangement came into operation in November, 1917.

Control of importers' prices inevitably led to control of merchants' and manufacturers' also. Regulations governing the commission made by small tool merchants were drawn up in December, 1917, on the basis of the practice ruling in the trade before the war.

In February, 1918, the control of makers' prices was definitely taken in hand, and the Small Tools Order issued in May embodied the regulations. They were considerably less detailed than those operating with regard to machine tools. Control was to be exercised in the simplest possible form, and wherever possible the submission of prices by individual firms was to be avoided. Maximum prices were to be, in the case of tools of standard type, those obtaining in the permit holder's business at the time his permit was issued, and in the case of special tools, such as were approved by the Ministry from time to time. All prices were subject to revision at any time by the Ministry, and if found to be too high, refunds might be required.[1]

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[1] Appendix XI.

The Small Tools Order came into operation on 1 June, 1918, but as a result of the Armistice control became unnecessary, and it was withdrawn in February, 1919.[1]

V. Relations with the Trade—Supply of Labour.

As the organisation for control was developed, the relations between the department and the trade necessarily became closer, and the effective working of the regulations depended on the harmony with which these relations could be maintained. Though from the departmental point of view close control meant efficiency, economy and increased production, from the point of view of the manufacturer it might easily appear irritating interference and increased burdens. If in controlling the trade the department experienced considerable difficulties, so did the manufacturers in satisfying the demands of the department for information as well as for speedy execution of orders, in obtaining labour and material, and in dealing with sub-contracting on the scale necessitated by the increased demand. It was impossible that the period of control should pass without friction of any kind; it says much for the goodwill shown by both sides that such friction as there was never hindered output, and that cordial relations between the Ministry and trade representatives were maintained to the end.

(*a*) Attitude of the Trade towards Control.

Undoubtedly one of the reasons for the smooth working of control was the presence of the Machine Tool Advisory Committee, but that body did not always represent adequately the feelings of the whole trade, and from time to time complaints reached the department, through the medium of the Machine Tool and Engineering Association. Two deputations in particular were sent, one in June, 1917, and another in June, 1918, and the opinions expressed by these may be taken as showing the principal grievances of the manufacturers. The root of their opposition was undoubtedly to be found in the control of prices, which, they contended, put a premium on inefficiency. In their view, where a firm made large profits it was due to better business methods, and could not therefore be deemed profiteering. In seeking to reduce war profits the Ministry was eliminating the incentive to efficiency, and adopting a fundamentally wrong policy. Even admitting, for the sake of argument, the necessity of price control, the makers urged that the system instituted by the department was very inquisitorial, that returns for a period of seven years were quite unnecessary, and involved an undue amount of work considering the depleted state of clerical staffs, as well as the disclosure of firms' private business concerns to their competitors.

[1] See History of the Machine Tool Department, Part II. by Sir A. Herbert (Hist. Rec./H/1700/1); Memorandum of Price Control, by Sir A. Herbert and Mr. Edward M. Iliffe (Hist. Rec./H/1700/4); Notes on T.M.2 by Mr. P. V. Vernon (Hist. Rec./H/1700/2); Minutes of Machine Tool and Small Tool Advisory Committees and Merchants and Importers' Advisory Panel.

The policy of the department in insisting on merchants' discount on Government orders was another great grievance of the trade, as the makers considered that this practice penalised firms who dealt through merchants as against those that dealt directly. The control of small tools also evoked considerable discontent, as it was felt that the hardships of control would press particularly heavily on a trade in which the price of articles was often so small that the profit allowed would not cover the increased cost of production under control, and in which the difficulty of fixing standard prices was particularly great owing to variations in design, and in quality of workmanship and material even in the same class of article.

In answer to these criticisms the department pointed out that the practice of obtaining merchants' discount was a general policy in the Ministry, and that the machine tool trade was not being treated any differently from other trades. The control of small tools was necessary because of the profiteering which had been steadily increasing throughout the trade and was particularly flagrant in certain cases. As regards the whole question of price control, the views of the trade and the department were diametrically opposed. The latter disputed the view that the method adopted put a premium on inefficiency, and said that since control was considered to be in the national interest, it would continue in force, though concessions might be made to mitigate hardships where they could be shown to exist in individual cases. The department justified the system of returns on the ground that information over a period of seven years was necessary to obtain a basis of comparison between war turnover and peace turnover on which the whole system of price control was based, and argued that in efficiently managed offices the information should be readily accessible and should not entail an undue amount of extra labour.

Dissatisfaction expressed by the trade really centred in the question of administrative control; of dissatisfaction with Ministry direction in regard to methods of manufacture there appears to have been comparatively little. This side of the department's activity constituted one of the most valuable parts of its work. The lack of organisation and the general conservatism which prevailed in the trade at the outbreak of war left room for much assistance in speeding up output, and in the introduction of new processes and new methods of production.

This work was very largely done through the inspectors of the Machine Tool Department, who visited firms and advised them how best to overcome their difficulties, and to produce more rapidly with less efficient labour. Standardisation of tools may be quoted as an example of the work done to increase industrial efficiency, and the importance of this may be gauged by the fact that while in January, 1916, only 14 taps were known to be standardised for munition work, in May, 1917, the number was 2,361. The specialisation of firms on particular types of machines was encouraged by the department, and insisted upon in 1918 when the withdrawal of American supplies made closer organisation a necessity. Limitation of design was another method adopted somewhat earlier to achieve the same end: in October, 1917, firms were forbidden to manufacture machines of new

design without sanction, and similarly sanctions were but sparingly given to merchants and importers to deal in machines which hitherto they had not touched. Manufacturing processes were supervised to the extent of laying down a rule that a single coat of chocolate coloured paint only was to be given to machines as a finish. In respect of trade secrets and the co-operation of firms with one another, the department had a hard battle to fight, for the jealous guarding of trade secrets may be said to be an axiom of industrial policy, and the extent to which it was successful shows that the machine tool firms, in spite of grumbling and evasion of regulations, were really anxious to co-operate with the Ministry in the matter of getting the utmost possible output.

(*b*) Evasion of Regulations.

That evasion of the regulations took place is only to be expected. Especially in the earlier period of control the temptations to evasion and the loopholes provided by an incomplete organisation were many. Tools were supplied without sanction, accounts were kept irregularly to conceal the fact, unauthorised advances in selling prices were made, subcontracting, importing and merchant regulations were not observed. Second-hand machines were sold as scrap; in fact, every possible type of evasion that ingenuity could suggest appears to have occurred. In July, 1916, an inspector reported that, "in practically every case I have visited breaches of the regulations are taking place." Firms when brought to book pleaded that they "had been no worse than other firms." The institution of the permit system in August, 1916, enabled the department to check very considerably these irregularities, since a threat of withdrawing the permit to trade was generally sufficient to reduce recalcitrant firms to order. If they refused to refund excess charges (and evasion of price regulations were by far the most usual), the department carried out its threat. During 1917 and 1918 a number of firms had their permits cancelled, and though applications for renewal were frequent they were hardly ever sanctioned. In this respect the department consistently enforced a firm, almost severe, policy, for, as the Machine Tool Advisory Committee said in one particularly flagrant case, "if drastic action were not taken, their effort to enforce the regulation . . . would have been a failure." That a severe policy justified itself may be gathered from the fact that evasions of the regulations gradually became less and the percentage of cases, where they could be traced, was ultimately not large. Mr. John Varley was responsible for the supervision of the Investigation Section, and it was largely due to him that the regulations were in the end so consistently observed.

(*c*) Supply of Labour.

The labour problem in the machine tool trade was always a difficult matter, both to the department and to the trade. Machine tool manufacture requires highly skilled labour, and yet the rate of wages was lower during the war than in many other skilled trades where piece-work prices were taken into account. At the beginning of the

war the trade was one of the worst sufferers from the general migration to the army and direct munition making. Neither the men themselves nor the authorities seem to have realised at first the true significance of the machine tool industry, and consequently the depletion of the ranks of skilled machine tool workers became serious. As soon, however, as the mistake was realised, steps were taken to obtain the release of skilled men from the army and the reserves of skilled labour engaged upon work not of national importance, such as the jewellery and the joinery trades, were drawn upon.

In August, 1915, the Machine Tool Advisory Committee discussed the possibility of dilution with unskilled male labour and female labour, and manufacturers were circularised on the subject. From this time onwards a steady campaign to persuade firms to adopt female labour, and to educate them in the use of it, was carried on, but apparently manufacturers were not eager to co-operate in this respect. A certain number of firms tried the experiment: in September, 1915, it was reported that 22 firms had arranged female labour, and Messrs. Alfred Herbert, Ltd., said that it was proving most satisfactory. But judging by the number of circulars that were issued to the trade (October, 1915, November, 1915, February, 1916, when the slow progress of dilution was commented upon), this action was not general, and firms applied for skilled men to do work which unskilled labour could have performed with comparatively little training. The necessity of obtaining skilled labour for developing industries such as aircraft production, and the different "combs-out" as the war proceeded, gradually forced on manufacturers a more progressive policy. The proportion of women to men employed rose considerably. In January, 1916, only about 2·5 per cent. of the labour employed in the trade was women's labour; in June, 1917, it was 10·7 per cent.; in September, 1918, 24·4 per cent.[1]

During 1915 and early 1916 the policy of the Ministry appears to have been to make the machine tool trade a favoured industry in respect of skilled labour with the idea that when the pressure of demand for machine tools became less, these men could be drafted to other trades where the demand was more urgent. Unfortunately, owing to the constant extensions to old works and the building of new factories to increase the output of old types or to provide new types of munitions, the pressure of demand on the industry never became appreciably less[2], and thus a struggle set in between the Government and the manufacturers for the possession of this skilled labour. In July, 1916, the machine tool trade was asked to release 2½ per cent. of their skilled men for work in the National Projectile Factories and for aeroplane construction; in December there was a proposal to remove 3,000 skilled men out of a total computed at 14,000 in the machine tool and crane trades; and in October, 1917, 1,000 men were to be withdrawn for aeroplane work. The manufacturers met these proposals with energetic protests, and generally some modification was made to meet cases where particular hardship was inflicted. The figures of labour employed show, however, that the Ministry was to some extent

[1] Appendix XIII. [2] Appendix XII.

successful in its policy. In January, 1916, the total labour employed on machine tools was 42,269 workpeople; in January, 1917, it had fallen to 36,401; in January, 1918, to 29,000; while at the date of the Armistice it was about 27,000.[1] This result was achieved in spite of the continued pressure of demand by the more economical use of labour and by improvement in manufacturing methods.

The withdrawal of restrictions on the movement of labour and the removal of protection of skilled men reacted badly on the labour in the trade. The Machine Tool Advisory Committee protested against debadging and the withdrawal of leaving certificates. The latter especially proved a hardship, since migration from the industry set in at once. In 1918 this migration had assumed such serious proportions that manufacturers complained that it was threatening to destroy their whole organisation for post-war competition, since, though they would have suitable equipment, their skilled labour would have dwindled to a minimum. The attempt of some firms to cope with the difficulty by instituting bonus systems met with opposition from other firms, and no successful remedy had been found when the Armistice was signed and the whole labour question entered upon a new phase.[2]

VI. Liquidation of Contracts.

(*a*) LIQUIDATION.

Two days after the signing of the Armistice, the question of liquidation was discussed by the Machine Tool Advisory Committee. It had been arranged by the Minister that the Controller of the Machine Tool Department, Mr. Edward M. Iliffe, was to be responsible for the liquidation of all orders for machine tools, small tools and cranes. Mr. Iliffe was fortunate in securing the help of Mr. J. W. Milne, who was appointed Assistant Liquidator; and the Advisory Committee expressed its willingness to give "disinterested advice in helping the Ministry in the transition stage from war to peace."[3] Machine tools presented the greatest difficulty, since by far the larger amount of the contracts concerned came under this heading, and as the whole of the output had been closely regulated by the Ministry, the contractor could not be held responsible for delays in delivery or subjected to arbitrary cancellation without compensation on this account. In the case of small tools and cranes, output had been regulated in a few instances only, and therefore the general principles laid down by the Ministry with regard to cancellation and compensation could be applied.

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[1] Appendix XIII.

[2] See Deputation of Members of Machine Tool and Engineering Association (D.D.G.(T)/921); Notes on T.M.2 by Mr. P. V. Vernon (HIST. REC./H/1700/2); Minutes of Machine Tool Advisory Committee; *Review of Munitions Programme.*

[3] Minutes of Machine Tool Committee Meeting 256.

As far as liquidation was concerned, machine tools were divided into two classes : (*a*) Machines ordered for a special purpose, for which there would be no market after the cessation of hostilities ; (*b*) general purpose machines, which could be used for post-war work.

It was considered by the department that contracts falling into the first class should be dealt with individually, the contract being cancelled immediately and the amount of compensation being assessed by Government inspectors according to the work done under the contract, and on the lines laid down in the break clauses attached to all machine tool contracts. Contracts falling into the second class should be treated generally. If delivery to the Government were not required, contractors should be asked to relieve the Government of all its orders on the basis of a compensation of from 10 per cent. to 15 per cent., irrespective of the amount of work done upon the machine. The payment of this compensation would really be an economy to the Ministry, since if the machines were delivered they would be put to a certain amount of expense in finding a customer and selling the machine, as well as risking a possible depreciation in price in certain classes of machinery. In addition the proposal would relieve the Ministry of an enormous amount of work and responsibility.

These proposals were approved by Sir Gilbert Garnsey and the Minister, and the amount of compensation to be paid on standard machines was fixed at $12\frac{1}{2}$ per cent. The members of the Machine Tool Advisory Committee undertook, as far as their firms were concerned, to accept a general settlement on these lines, and the work of liquidation was begun. By far the greater number of contracts were settled by payment of the $12\frac{1}{2}$ per cent. compensation. Where there was any uncertainty as to whether machines were standard or not, the Machine Tool Committee adjudicated : for example, a contract had been placed with J. Butler & Co. for slab milling machines, which they decided could not be regarded as standard, and the Ministry therefore agreed to accept delivery and dispose of the machines themselves. In another contract with Kendall and Gent, where the machines were judged to be special, compensation at the rate of $22\frac{1}{2}$ per cent. was paid. In some cases it was found that machines, though they could hardly be regarded as special, had certain departures from standard type which would render sale difficult, and in such cases the committee recommended that a higher percentage than the normal $12\frac{1}{2}$ per cent. should be paid : for example, on a contract with Messrs. Craven Bros. for double-headed shaping machines. The value of the completed orders for machine tools, small tools and general machinery at the date of the Armistice slightly exceeded £3,100,000. Of this total the various Government Departments for whom the orders were placed stated that they required deliveries to the value of over £1,000,000, which left contracts to the value of approximately £2,100,000 to be liquidated in the most economical manner possible. Of this total deliveries were accepted to the value of slightly over £200,000, and the goods passed to the Disposal Board for sale. Of the remainder compensation was paid to the extent of a sum slightly in excess of £220,000, or 11% of the value of the goods cancelled,

which left a saving of approximately £1,680,000, or 89% of the commitment value. These figures were subsequently modified, as instructions were received for further orders to be cancelled, but the percentage cost of the liquidation of contracts not required remained substantially unaltered.

The liquidation of contracts for imported machine tools was, with the approval of the Merchants and Importers' Advisory Panel, carried out on the general lines adopted in the case of British made machines. It was decided to withdraw all restrictions on the selling prices of imported machine tools from 9 December, 1918.

(*b*) Disposal of Government Property.

The disposal of Government-owned machine tools in the various national factories and loaned to private firms was undertaken by the Surplus Stores Disposal Board, and did not come within the scope of the Machine Tool Department.

(*c*) Demobilisation of Committees.

By the end of April, 1919, it was decided that there was no longer any reason for retaining the services of the Machine Tool Advisory Committee, of which Provost W. B. Lang had acted for nearly two years as a most efficient Chairman. It was therefore dissolved, having held 270 meetings since its inception on 20 July, 1915. The Merchants and Importers' Advisory Panel and the Small Tool Committee had already been dissolved in February. The Machine Tool Department continued in being to finish up the work of liquidation, but with the demobilisation of the committees its close and continuous connection with the trade was severed. Of the value of the committees' work there can be no two opinions. Though as advisory bodies they were only able to make recommendations, their representative character and intimate knowledge of trade conditions gave their recommendations very considerable force and their close co-operation with the Controller and executive officials of the Machine Tool and other departments of the Ministry prevented their recommendations from degenerating merely into pious aspirations. It is true also that the regulations for the control of the industries were almost invariably proposed by the Controller of the department to meet constantly changing circumstances. Thus the Committees did not to any extent initiate policy. But in so far as these regulations were submitted to the committees with the reasons which prompted their suggestion, and then discussed by them, and often modified and improved, they exercised a considerable influence on their application. The machine tool trade was the earliest and ultimately the most closely controlled of all industries, and the success of the experiment was largely due to the fact that control was carried out with the consent of the trade itself, expressed through its representatives on the Advisory Committees.[1]

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[1] See Minutes of the Machine Tool Advisory Committee.

CHAPTER III.

BALL BEARINGS.[1]

I. Introduction.

Experience of warfare on the scale on which it was waged during the years 1914 to 1918 revealed unsuspected weaknesses in the industrial organisation of all the belligerent countries. In Great Britain one of these weaknesses was the failure to realise early enough the importance as a limiting factor in production of a comparatively small component in manufacture, or of certain kinds of industrial equipment. Instances of the latter are machine tools and gauges, the inadequate supply of which was one of the prime factors in delaying and limiting the output of munitions in the early months of the war. A crucial instance of the former may be found in the history of ball bearing supply.

Bearings are a component of all apparatus for mechanical transport; whether it be bicycle, motor, tractor, or aeroplane, they are an essential part of the motor machinery. For commercial purposes a steady demand for bearings must always exist, and even before the war there was a tendency for this demand to become larger as motor transport played an increasing part in industrial organisation. The possibilities of mechanical transport revealed early in the war resulted in a sudden increase in demand, and when the part to be played by aeroplanes and tanks was realised by the military authorities, a situation developed which amounted practically to a revolution in the whole conception of the scale and relative proportion of munitions supplies. The reaction of this on the ball-bearing situation was to produce a demand which the existing organisation was totally unable to meet, of which even the manufacturers had but little prevision, and for which correspondingly little attempt had been made to create fresh sources of supply. The failure to deal with the situation seems all the more remarkable in view of the fact that the pre-war demand had been met largely by importation, a great proportion of which (two and a quarter million bearings annually) was from Germany. To this extent, therefore, supply was automatically reduced in August, 1914. Thus there would have been difficulty in meeting a normal demand in such circumstances: to meet an extraordinary one was obviously impossible. Yet beyond individual efforts on the part of one or two ball-bearing firms to extend their works, nothing effective was done until the middle of 1916, when the

[1] See Record of Ball Bearing Supplies, prepared by the Ball Bearings Branch, and Appendix containing copies of agreements, reports, correspondence and statistics (Hist. Rec./H/1700/7).

situation was absolutely critical. A conference called to discuss the matter in July revealed the fact that even on the manufacturers' own estimates, which were likely to be liberal, only about 55 per cent. of the existing demands could be met from home supplies, and the decreased importation could not possibly supply the remaining 45 per cent. Belated efforts were made to remedy the evil; central organisation was set up and large extensions to factories were at once put in hand.

Unfortunately, demand did not wait for these efforts to bear fruit and produce equilibrium. The rapidity with which aerial and mechanical warfare came into play as decisive weapons in the field caused it to go up by leaps and bounds, and in July, 1917, there was little improvement in the situation. At this date the total output, both from home and foreign sources, was only 85 per cent. of the estimated requirements to the end of 1917, while the new programmes of the Aeronautical Department and of the Mechanical Warfare Department would raise the demand in 1918 far beyond anything the existing sources could supply even when the extensions authorised in 1916 came into full operation.

Drastic action was imperative to save the situation. An Advisory Committee was appointed to review the whole position, central organisation was improved, and instructions for further large extensions were issued to the chief supplying firms at home. Pressure was put on foreign sources to increase their supplies and American help was obtained to the fullest possible extent. The result of this concentrated activity was that slowly matters began to improve. The discrepancy between supply and demand diminished, and something approaching equilibrium was apparently obtained in 1918. But the facts revealed in 1916 and 1917 show that it was only the energetic action of the Ministry that prevented disastrous consequences resulting from the previous lack of foresight, and even their best efforts could not prevent delay in the output of tanks and aeroplanes at a time when the greatest possible supply of these was a factor of vital importance in military operations.

II. Organisation and Functions of the Ball Bearings Branch.

(*a*) Organisation of the Branch.

For industrial purposes ball bearings are included with other appliances in the term small tools, and thus their history properly belongs to that of the Small Tools Section of the Machine Tool Department. An attempt was made at first to deal with them in this section. But the nature and organisation of the ball bearing industry at the outbreak of war was such that the problem of supply differed in many respects from that of small tools in general, and it was ultimately felt that an independent organisation was necessary to deal satisfactorily with the difficulties created by war conditions. Thus a separate branch was established which remained part of the organisation of the Ministry of Munitions till the termination of the war.

Administrative action was first taken in the summer of 1916. In March the Minister had been approached by the French Government to assist them in obtaining increased supplies of balls from the Hoffmann Company, who were, in the words of M. Albert Thomas, " presque l'unique fournisseur des Alliés,"[1] and doubtless this request led to a review of the state of the whole industry, which revealed the urgent necessity for immediate action. In July a conference was held at the Ministry for the purpose of discussing the situation with the representatives of the departments chiefly interested in the supply, and Mr. J. D. Steven, the Director of the Small Tool Section of the Machine Tool Department, was instructed to extend the activities of his section to cover the ball bearing industry.

In spite of the efforts of the Small Tool Section, further organisation became necessary in July, 1917. An Advisory Committee, consisting of Sir Alfred Herbert, Mr. Steven and Mr. Percy Martin, Director-General of Petrol Engine Supply, was then appointed, and as a result of their report the Minister decided that a Ball Bearing Branch should be established, affiliated to the Machine Tool Department and working in close connection with the Aeronautical Supplies Department. Mr. Steven was appointed Director of the branch in addition to his work as Director of the Small Tools Section.

A year later all connection with the Machine Tool Department ceased. The branch was at the service of so many departments, not even confined to the Ministry, that it was found that affiliation to any particular one resulted in confusion. So from July, 1918, it continued its work as a self-contained section, grouped for establishment purposes only with the Aircraft Production Department and responsible to Sir Arthur Duckham as Member of Council.

(*b*) Functions of the Branch.

The work done by the Ball Bearings Branch can be divided into three sections, the provision of bearings of the types and (as far as possible) the quantity required, their distribution among the services requiring them in accordance with the varying urgency of their demands, and the control of exports and imports. To understand the problem which the branch had to face, the position of supply when the matter was first taken in hand by the Ministry and the conflicting nature of the demand must be briefly indicated.

The material included under the general term " ball bearings " should be more specifically divided into ball bearings, roller bearings, steel balls and steel rollers. For the supply of these there existed in England six firms, but one only, the Hoffmann Manufacturing Company, manufactured all classes and sizes of the four components. The Auto Machinery Company manufactured steel balls as well as bearings, but the other four firms manufactured bearings only, either ball or roller or both, and were dependent for their supply of balls either on the Hoffmann Company or on foreign sources. Thus the

[1] Hist. Rec./H/1700/7, Appendix B1 (a).

Hoffmann Company were the key to the whole position as far as the home supply was concerned, and on this firm's ability to maintain its output depended the output of the whole industry. In addition to these six firms, there were two foreign sources of supply, the Svenska Kullager Fabriken of Sweden, supplying ball bearings complete and some steel balls, and the Schmidt-Roost Company, Switzerland, supplying ball bearings complete only. The Swedish House was represented in England by the Skefko Company, of Luton, one of the six firms alluded to above, and the S.R.O. Company had an English agency in London. The great drawback to supplies from these two firms was that all the raw material for manufacture had to be exported from England, and thus to the dangers and uncertainty of transport was added the difficulty of keeping them adequately supplied with material. Up to the middle of 1916 there was no appreciable importation of balls or bearings from America, and generally the American product was not equal in quality to the British product. Taking both home and foreign sources of supply into consideration, the total ball and roller bearings available in October, 1916, were 208,652 per month.[1]

For this supply there existed the most varied demand, as ball bearings play an essential part in many industries. The chief Government Departments requiring supplies in 1916 were the War Office, the Admiralty, and the Ministry of Munitions (the Mechanical Transport Department, the Central Clearing House, and the Service Bicycles Section). Later developments in the matter of tanks increased the requirements of the Mechanical Warfare Department enormously, and as the aeroplane programme was extended, those of the Aircraft Production Department became equally urgent. Outside the Government Departments, supplies were demanded by the Commission Internationale, the Russian Government, the Dominions and India. Beyond these, again, there were the requirements of private manufacturers, especially cycle makers, but as this work fell into "Class C" it need hardly be considered in dealing with the relation between supply and demand. Inquiries addressed to the different departments concerned, to foreign Governments, and to Colonial representatives elicited requirements of 246,404 bearings of all classes monthly, and this was not by any means the total, since the requirements of the Dominions and India had not been received when the report on the matter was made. Putting this beside the figures of supply, there was a deficiency of nearly 38,000 monthly,[2] and if the importation figures were deducted, the deficiency in the home supply was shown to be at least 103,000, or 42 per cent. This is the figure which should really be kept in mind, since there was the possibility of importation being stopped entirely and, in any case, dependence on importation was not a policy to be commended.

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[1] Based on estimates by supplying firms.

[2] This is the estimated deficiency; actually it was greater, because the firms' estimates of output were too sanguine. See below, p. 89.

With such a deficiency the necessity of increasing supplies was obvious. Three methods suggested themselves, control of the industry on the lines instituted by the Machine Tool Department, extensions to home factories, and a considerable increase in importation. All these expedients were adopted, but their value as sources of increased supply varied very much. Comparatively little could be done to increase output by control since the industry had been specialised before the war to an extent which left practically no field for increase by modernisation of method. Standardisation on any large scale was impossible, because the existing types and sizes were so numerous that the time involved in effecting alterations would more than counterbalance any ultimate good arising from standardisation. Measures had already been taken to meet the labour difficulty and to make the utmost use of the available labour by organising night shifts. The policy, therefore, which was being applied with considerable success by the Machine Tool Department generally could not hope to be successful in this particular matter, and it was necessary to look to other sources for a real solution of the problem. Increased importation, though a necessity, was, as has been said, not an ideal policy. The department was therefore forced to resort to the third method, large extensions of existing factories in England, and consequently its activity in this direction far outbalances that of the Machine Tool Department.

The importance of the work done by the branch in allocating output is made clear by the facts of supply and demand. The priority classification, which for bulk supplies was P.4, automatically gave manufacturers some guidance as to relative urgency of demand, and supplementary instructions were issued by the department from time to time. For example, special instructions were given to the Hoffmann Company in January, 1917, to give aircraft orders preference over mechanical transport orders, and at various dates instructions were issued for imperatively urgent work. But in the spring of 1917, as the aeronautical demand increased both in amount and in urgency, the position of manufacturers became very difficult. The instructions of the inspectors of the Aeronautical Department clashed with those of other departmental inspectors quoting a high priority for their orders. This led to a definite ruling being made that absolute control of the order of execution of supplies by the manufacturers was vested in the Ball Bearings Branch, and that all inspectors requiring a special priority for their orders must take up the matter with the branch and not with the firm executing the order. This action relieved the manufacturers very considerably, but led to the branch being flooded with departmental requests for preferential treatment for special contracts. As it was impossible to satisfy all individual applications, it became necessary to devise some system whereby the rival claims of different departments could be automatically adjusted.

The method adopted was that of departmental allocation on a percentage basis. The requirements of the respective departments were ascertained, and a proportionate percentage of the total available supplies was allotted to each department, which would then determine

for itself the relative precedence of orders placed on its behalf, so long as the allotted percentage was not exceeded. Each department thus benefited automatically by every increase in output, and the relative balance of demand was maintained. This scheme met with the approval of all departments except the Aeronautical Department, whose increasing programme was a source of great anxiety. At one period this department attempted to safeguard its supplies by placing orders on its own responsibility with three general engineering firms, the Blackstock Engineering Company, Messrs. Vickers, of Crayford, and the Components Munitions Company, Limited. These firms were instructed to manufacture ball and roller bearings in connection with the A.B.C. engine programme. The prejudicial effect of such independent action on allocation of supplies was obvious, and the Ball Bearings Branch at once took up the matter with the Aeronautical Department. The working of the scheme appears to have shown that the department's premonitions of a shortage for really urgent requirements were not fulfilled, and the increasing rarity of departmental requests for assistance during 1918 show that on the whole the scheme was a success in working. As supply more nearly met demand, the importance of allocation naturally became less, but it always remained as a means of dealing with what proved to be one of the greatest difficulties the branch had to face, the conflicting demands of the number of departments interested in the supply.

III. Control of the Ball Bearing Industry.

(*a*) Control of Sale and Manufacture.

The order under which the ball bearing industry was rigidly controlled was published on 1 November, 1917, as a result of the decision to create a Ball Bearings Branch at the Ministry, which should relieve the Small Tool Section and enable more attention to be paid to the matter of ball bearings. Under the terms of the order nobody could manufacture or deal in ball bearings, roller bearings, or any part of these without a licence issued by the Ministry. The qualifications for a licence were that the applicant must be

(1) A bona fide manufacturer of balls or ball bearings;

(2) A recognised agent for a foreign firm or an independent importer of three years' standing prior to 31 December, 1917;

(3) A dealer in balls and ball bearings as part of the ordinary course of his business as a merchant or garage proprietor with a business of three years' standing as in the case of the importer.

Under these conditions 131 licences were granted. Exemptions from the order were made for the purchase of ball or roller bearings within the United Kingdom, and for the sale of bearings as part of a complete machine or for automobile repairs.[1]

[1] See Appendix XIV.

Under the terms of the licence manufacturers had to submit weekly returns of their output and orders in hand, and importers and dealers monthly returns of stock, purchases and sales. These particulars enabled the department to grade output according to the urgency of demand and to keep in touch with stocks which would be available in cases of emergency.

(*b*) CONTROL OF PRICES.

In January, 1918, price control was instituted owing to the increasing amount of exploitation which came to the notice of the branch.

Representatives of the trade were consulted, and it was laid down that on orders up to and including £10 in value a maximum percentage of 25 per cent. might be added to the net cost on delivery to the customers' warehouse by the manufacturers, while on orders above £10 the maximum percentage was to be 12½.

On the whole, control was accepted by manufacturers and dealers as an inevitable necessity. A certain number of traders, as might be expected, attempted to do business without a licence, but cases of this kind were often tracked by the help of the censoring authorities. Gradually the recalcitrant firms came into line, and control worked smoothly till the order was suspended on 7 January, 1919.

IV. Extensions to Factories.

The amount of financial assistance given by the Ministry to ball bearings firms for extensions varied considerably according to the importance of the output, both as to type and quantity, and to the general efficiency of the firms. Of the six firms previously mentioned, four made considerable extensions to their works with Government assistance. These were the Hoffmann Company, the Skefko Company, the Electric and Ordnance Accessories Company, and the Ransome and Marles Bearing Company. One, Messrs. Mair, Nixon & Ferguson, of Kettering, received slight assistance for plant additions (£1,000 was lent by the Ministry in September, 1917), while the Auto-Machinery Company, of Coventry, rendered no assistance at all. In marked contrast to that of other firms, their attitude was " the reverse of helpful."[1] They practically demanded that the Government should defray the whole of the cost of any extensions, and were so antagonistic that, except for insisting on the installation of certain machine tools essential for an important aeronautical contract, the branch made no definite attempt to influence the firm's policy, and the output of the company remained stationary at 9,000 bearings a month. The failure of the Auto-Machinery Company to co-operate was, however, to some extent counterbalanced by the enterprise of the Rudge Whitworth Company, who with Government assistance built an entirely new factory for the production of ball bearings.

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[1] HIST. REC./H/1700/7.

The help rendered by the six firms varied markedly, and this variation must be put down to the business organisation of the different firms, since the difficulties which faced them were for the most part general. All suffered from shortage of building materials and labour for their extensions; all found great difficulty in obtaining the necessary plant to equip them; and all had to face the usual problems of shortage of raw material and productive labour. The Ball Bearings Branch gave all possible assistance in these matters, working in close co-operation with the Machine Tool Department, the Labour Supply Department, and the Iron and Steel Department. But the value of its help depended largely on the co-operation of the firms concerned, and a comparison of the results attained by the different firms under practically similar general conditions shows that ultimately the deciding factor in increased output was the efficiency and goodwill of the individual manufacturer.

(*a*) THE HOFFMANN MANUFACTURING COMPANY, LTD., CHELMSFORD.

The Hoffmann Company was already the leading firm in the ball bearing industry when the Ministry took up the problem of increasing output. In July, 1916, they were producing approximately 90,000 bearings a month and had extended their works out of their own resources to attain this output, their capacity early in 1915 being about 72,000 monthly.

On 20 July, 1916, a meeting of representatives of the Ministry and the Company was held to discuss the question of further extensions. It was arranged that these were to be put in hand at an estimated cost of £75,000. The Ministry was prepared, if necessary, to make advances from time to time up to a sum of £140,000 to cover the cost of these and the earlier extensions and to supply working capital. Such advances were to bear interest at 1 per cent. above the current Bank of England rate and were to be repaid within three years of the termination of the war. No definite increase in output was mentioned in the agreement nor was the date of completion of the extension stipulated, though time was to be "the essence of this agreement."[1] In October, the firm said they hoped to finish the extensions by March, 1917, and to increase their output by 50 per cent. on that obtained during the early months of 1915. This meant that at least 108,000 monthly might be expected, and 120,000 was the amount which they hoped to reach ultimately.

Serious delays were experienced with regard to the extensions, which led to a special liaison officer being appointed to follow up each difficulty as it arose. This improved the situation very considerably, and output on a small scale began in May, 1917. In July the extensions were giving a substantial output, and by January, 1918, the output of 120,000 monthly was being considerably exceeded.

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[1] HIST. REC./H/1700/7, Appendix A.4.

A second extension was undertaken in June, 1917, as a result of the sudden increase in the aeronautical programme at that date. The capacity of the factory was to be increased to 175,000 monthly by June, 1918, and the firm considered that the cost of the necessary new buildings and plant would be from £500,000 to £750,000. Provisional sanction was given by Sir Arthur Duckham in order to avoid delay, and the firm prepared plans and placed contracts for the work. A formal agreement was not, however, made, because in August the question arose of taking over the Hoffmann works entirely, and the extension became involved in this. As a result of the taking over of the factory, the Department of Factory Construction took the extensions in hand and they were well under way by December, 1917. Difficulties with regard to supplies of steelwork then intervened, so that it was the summer of 1918 before the first sections were ready and equipped. After that date much more rapid progress was made, and at the date of the Armistice practically the whole of the extensions were in operation, and the output for October (five weeks) reached nearly 230,000 bearings.

Messrs. Hoffmann had been extremely unwilling to assent to the extension scheme of 1917, as it would treble the pre-war capacity of the works, and they feared that their post-war business would not be big enough to enable them to utilise such extensive buildings. Moreover, they would have difficulty in finding working capital and were unwilling to increase their indebtedness to the Ministry. When the Ministry insisted that the extensions must be carried out in the national interest, they suggested that the works should be taken over as a national factory, to be carried on by the present Managing Director of the Company, if the Ministry so desired. The Ministry was not very willing to adopt this course, and pressed the Company to extend their works with Government assistance. Negotiations on these lines were going on when the scheme for the erection of a new factory by Messrs. Rudge Whitworth was brought forward. If this was to succeed it was essential that the co-operation and technical assistance of Messrs. Hoffmann should be secured. But it was unlikely that the firm would assist in building up a new business which would compete seriously with their own organisation after the war without a very substantial *quid pro quo*. The Government therefore began to consider the idea of purchasing the Hoffmann business outright and thus taking the two Managing Directors into Government service in order to utilise their business capacities not only at the Hoffmann works, but also at the Rudge Whitworth factory.

Negotiations for purchase were begun in August, 1917, and in September provisional terms were agreed on by the Ministry and the Company. The assets of the Company were to be valued as at 30 September, 1917. From this valuation were to be deducted all liabilities and outgoings of the Company up to the same date (including the liability for the current Ministry loan), but not any liability incurred for the new extensions. The difference was to represent the purchase price to be paid by the Ministry for the assets. In addition a sum of £515,000 was to be paid for the goodwill of the business. This figure

was arrived at by averaging the profits of the Company between 1913 and 1916 and taking five years' purchase. This offer was to be conditional on the two Managing Directors entering into an agreement to place their services unreservedly at the disposal of the Ministry.

The Company estimated that under this arrangement the purchase price for the assets would be £1,000,000. Accordingly, therefore, in asking for Treasury sanction, the Ministry named £1,515,000 as the total sum to be paid to Messrs. Hoffmann. The Treasury firmly refused to sanction this sum, saying that the sums both for the assets and the goodwill were extravagant. The Ministry pointed out that if the independent valuation judged the assets to be less than £1,000,000 the lesser sum would be accepted under the agreement, and justified the goodwill price by the urgency of the situation, and the value of the firm's technical knowledge, but the Treasury still refused to entertain the proposition. Protracted negotiations followed with the Company, and it was only a threat of taking over the works under the Defence of the Realm Regulations that finally brought the firm to making concessions that the Treasury would recognise as a basis for agreement.

In efficiency the Hoffmann Company appears to have reached a high standard. Their failure to attain their increased output by the dates specified was largely due to causes beyond their control, and when these difficulties were removed they made up their leeway with surprising rapidity. In order to meet the shortage of skilled labour, they instituted a training school at the works where unskilled labour was trained for different operations before being put to work on machines engaged on actual production. Dilution was carried out by the firm to a remarkable extent, considering the highly skilled nature of the work and the high standard of work guaranteed and maintained by the firm. In July, 1918, the percentage of skilled labour at work was only 6·4, the remaining labour being women (43·5 per cent.), boys (6·5 per cent.), and semi-skilled men. In reporting on the firm the liaison officer in charge of the extensions stated that the firm was " to be congratulated on the spirit in which they tackled every difficulty which arose, and on the manner in which they maintained the highest possible output even whilst changing over and occupying extensions as they became available."[1]

(*b*) SKEFKO BALL BEARINGS COMPANY, LTD., LUTON.

Besides acting as an agency for the Svenska Kullager Fabriken of Sweden, the Skefko Company was engaged on the outbreak of war in manufacturing bearings from materials supplied from Sweden, and the maximum capacity of their Luton factory when the question of extensions was brought up was about 20,000 bearings a month.

In the spring of 1916 the firm approached the Controlled Establishments Section with regard to putting in hand extensions to their bearing plant which would double the output and cost about £80,000. The Company was prepared to find this sum if the Ministry would agree, in dealing with the accounts of the Company as a controlled

[1] HIST. REC./H/1700/7.

establishment, to write down the expenditure to the post control value to the Company of the assets provided by the expenditure. To this proposal the Controlled Establishments Section assented, but owing to delays on the part of the Treasury, who were not satisfied as to the urgency of the matter, the formal agreement was still uncompleted in July, 1916, when the ball bearings conference took place. The conference considered that the extension was so important that authorisation should be given to the firm to proceed at once, with an assurance that an equitable arrangement would be arrived at with the Finance Department. Negotiations continued on the basis of the Controlled Establishments Section's letters, and eventually it was arranged that the cost of the extensions was not to exceed £100,000, and was to be written down to 60 per cent. of the cost of the buildings and 50 per cent. of the cost of machinery and plant.

Though time was stated to be "the essence of the agreement,"[1] the work of extension proceeded very slowly. A special officer was appointed early in 1917 to deal with difficulties, but the speeding up which followed a similar appointment in the case of the Hoffmann Company was noticeably lacking at the Skefko works. It was not till September, 1917, that the buildings were completed, and later still before they were equipped and in running order.

The position of the bearing plant was complicated by the erection of a new ball factory which was authorised in 1916. The advisability of the Company's manufacturing their own balls instead of depending entirely upon the parent firm in Sweden was urged at the Conference of July, 1916, but the manager of the Skefko works was decidedly opposed to this suggestion. Pressure was brought to bear on the firm by the Ministry, who felt strongly the necessity of cutting down imports and avoiding risks of loss in transport. The effect of this was that the Company agreed to erect a special ball factory to produce from fifteen to twenty million balls a year, at a cost not exceeding £125,000. Towards this sum the Ministry agreed to make advances from time to time, such advances to bear interest at 1 per cent. above the current Bank of England rate, and the whole loan to be repaid not later than three years from the termination of the war. The Company stated that they hoped to finish the factory and begin production by May, 1917.

This factory, however, shared the fate of the bearing extensions. The buildings were not completed till the end of 1917, and further delay was caused by the non-delivery of the ball-producing plant from Sweden. Even when the factory was equipped, labour could not be obtained to work it. As there was nobody at Luton skilled in ball production, experts had to be sent from Sweden to superintend the erection of the machines and to train labour for production. Difficulties with passports delayed the arrival of these men till the spring of 1918, and production did not begin till July, 1918. Even then the firm failed to attain anything like the promised output. The maximum

[1] HIST. REC./H/1700/7, Appendix A.5.

reached was under 6,000 balls a month, whereas the estimated output when the factory had been sanctioned more than two years previously was between nine and eleven thousand a month.

In spite of the unsatisfactory progress of the 1916 extensions, the need for increased supplies became so urgent in 1917 that it was decided that the firm must be instructed to put in hand new extensions. In August the Company submitted plans which would allow of an increase of 100 per cent. in their output of bearings and 50 per cent. in their ball output. In September, these plans were sanctioned by the Ministry, and an agreement was made for the carrying out of the scheme. The estimated expenditure was £50,000 on buildings and £175,000 on plant. Depreciation was to be allowed to the extent of 40 per cent. of the expenditure on buildings and 50 per cent. on plant. Advances bearing interest at 6 per cent. and not exceeding in all £500,000 were to be made by the Ministry to provide for capital expenditure and working capital, and the loan was to be repaid within five years from the termination of the war.

As in previous agreements, no date for the completion of the work was laid down in the contract, but the Skefko Company mentioned three or four months from the time of beginning work as a possible date. The building licence was issued by the Munitions Works Board in November, but in March, 1918, the buildings were far from finished. In a confidential report made to Sir Arthur Duckham at this date it was stated that the Company considered that the architect was responsible for the erection of the buildings, and did not therefore make much attempt to help in the difficulties arising in connection with material and labour. There was an unnecessary amount of importation of plant from Sweden and too much dependence on Swedish experts, no attempt being made "by the officials at the Luton Works to set the plant to work or to teach their employees how to operate the machines." [1] Moreover, the Company was very averse from dilution of labour and it was only after great pressure that they agreed to employ women. In view of these facts it was hardly surprising that the promised increase in output failed to materialise. A personal visit from Sir Arthur Duckham and changes in the management of the factory which took place about the end of April produced more enthusiastic co-operation, with the result that sections of the new shops were at work by the end of the summer, and at the end of October all the buildings were finished. The substantial increase in output which this promised was not however needed, since the Armistice was signed just as production was getting under way.

(*c*) The Ransome and Marles Bearing Company, Ltd., Newark.

The works of the Ransome and Marles Bearing Company originally belonged to Messrs. A. Ransome and Company, wood-working machinery manufacturers of Newark. In 1916 a new company was constituted which took over the factory for the production of bearings of large size

[1] Hist. Rec./H/1700/7, Appendix C.12.

and of special rather than standard type. The average output in 1916 was 5,500 bearings a month, which, considering the class of bearing manufactured, was equivalent to 10,000 a month of the Hoffmann or Skefko type.

Early in 1917 the Company began to extend their works in order to undertake a large War Office contract for aeroplane engine bearings. The estimated cost of the scheme was £37,000, and towards this the War Office contributed £21,637 13s. 4d., under the name of the "War Department Loan." Loan and interest were to be repaid by the deduction of 25 per cent. of the invoice price of the bearings supplied under the agreement. When in the summer of 1917 the question of a general increase in output was under consideration by the Ministry, the latter approached the firm to extend their scheme for the War Office and merge it into a Ministry agreement. Further extensions were to be made to the works at an estimated cost of £87,000, and the Ministry was to allow "as a grant to the Company"[1] 40 per cent. of the total expenditure on buildings and 50 per cent. of the total expenditure on plant and machinery. In addition the Ministry agreed to take over the amount owing to the War Office under the earlier agreement (£21,000) and to advance working capital as required. The grant for the extensions was to be deducted from the total indebtedness of the Company when the buildings were completed, and the balance was to be considered as a loan bearing interest at 1 per cent. above the current Bank of England rate, and to be repaid in full within three years from the termination of the war.

As a result of the original extension, it was estimated that the output would have risen to 15,000 a month by January, 1918, and an ultimate capacity of 30,000 monthly was expected when the further extension was completed. No definite date was laid down for the attainment of this figure, the "earliest possible moment"[2] only being stated.

In 1918 it was found that the original estimates for both extensions had been largely exceeded, and a supplementary agreement was entered into allowing for an additional £50,000 on the 1917 extensions. In addition provision was made for the erection of a small ball plant at a cost of £15,000, but owing to the signing of the Armistice no actual progress was made with this enterprise. In August, 1918, the total indebtedness of the Company to the Ministry was £209,000, of which £52,000 had been advanced for working capital and the remainder for the cost of the extensions.

Considerable delay occurred in the erection of the extensions owing to the shortage of labour. Lack of housing accommodation and low district rates of pay accentuated the difficulty. Progress grew more rapid in 1918, however, and at the end of the year the output was practically double that at the end of 1917.

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[1] HIST. REC./H/1700/7, Appendix A.13.

[2] HIST. REC./H/1700/7, Appendix A.13.

(*d*) The Electric Ordnance Accessories Company, Ltd., Birmingham.

No assistance from the Ministry was required by the Electric Ordnance Company till early in 1918. The works, which were the property of Messrs. Vickers, Ltd., gave a steady output of Timken Taper roller bearings at the rate of 4,000 to 5,000 a month during 1916 and 1917. In February, 1918, arrears in deliveries to the Mechanical Transport Department were so heavy that the Ball Bearings Branch undertook investigations, and got over the immediate difficulty by hastening deliveries of the machine tools required from America. These investigations showed, however, that no further output could be expected from the existing plant, and therefore when the Mechanical Warfare Department notified a large increase in their requirements in September, 1918, the question of extensions became urgent. The firm submitted their schemes at the end of September and approval was given by the Munitions Works Board on 14 October. Preliminary steps had already been taken by this time, and the extensions were therefore well under way when the Armistice intervened in November. According to the scheme, the estimated expenditure was to be £26,000, about equally divided between buildings and plant. The buildings were to be completed by 31 January, 1919, and the plant and machinery installed by 28 February. It was estimated that the output from these extensions would meet the demand of the Mechanical Warfare Department, but late in October the department put forward an amended programme with a 50 per cent. increase on their original demand. This could only have been met, had it materialised, either by further extensions or by importation of Timken bearings from America.

(*e*) Rudge Whitworth, Ltd., Birmingham.

The firm of Rudge Whitworth had not manufactured ball bearings before the war, but the need of supplies was so urgent that when the Company suggested taking up the industry in 1917, the Ministry gave the proposal most careful consideration. After considerable discussion with the Finance Department and the Munitions Works Board, the Company was authorised in August, 1917, to put in hand a combined bearings and ball factory to produce 80,000 bearings a month, together with their necessary equipment of steel balls. The work was begun on the basis of a draft agreement, which was converted into a formal one in January, 1918. Under the terms of this agreement the Ministry took over from the Company, under the Defence of the Realm Act, the land on which the factory was to be built, and empowered the Company to act as their agents in the erection and equipment of the factory. The whole of the capital cost was to be borne by the Ministry, to whom the building with its plant and machinery would, when completed, belong. The Company was then to lease the factory from the Ministry for the period of the war and one year afterwards at a rent which would be calculated to cover interest at 6 per cent. on the Ministry's total outlay, together with a sum to cover depreciation at the rate of 5 per cent. on two-thirds of the cost of the buildings

and 20 per cent. on one-half of the cost of the plant and machinery. At any time during their tenancy the Company had the option to purchase the factory at an agreed value, in which case the Ministry was to re-convey to the Company the land taken over under the Defence of the Realm Act. If the Company did not wish to exercise its option to purchase, the Ministry was to buy the land from the Company at its original cost, and the Company was to hand over the factory in good running order on the expiration of the lease. The whole output of the factory was to be sold to the Ministry at prices based on those of the Hoffmann Company, plus 15 per cent.

One of the chief reasons for taking over the Hoffmann Company in the autumn of 1917 had been to obtain the firm's assistance for the Rudge Whitworth venture, and therefore, in erecting and equipping the factory and deciding on the type of output, the Ministry worked on the assumption that the Tyseley factory would work hand in hand with the Hoffmann Company. The former works were to turn out standard types, while the latter concentrated on special and difficult types. The early manufacture of the Rudge Whitworth Company was thus carried on under the supervision of an expert from the Hoffmann Company. In May, 1918, bearings practically up to the Hoffmann standard were being turned out in small quantities. Where defects occurred, they were generally traceable to departure from the Hoffmann practice, and therefore the Company was instructed to adhere rigidly to Hoffmann methods rather than to try experiments and introduce "improvements" of their own.

Output was delayed by building difficulties rather than by failure to obtain the necessary plant, and it was not till June, 1918, that deliveries to contractors for the Mechanical Transport Department began. In August a large contract was placed with the firm by the Aeronautical Department, and deliveries under this order were rapidly being made at the time of the Armistice. Besides deliveries on contracts, the firm also sent a number of bearings into store. To October, 1918, the total output was 28,000 bearings, an achievement which was considered very satisfactory in view of the difficulties with which the firm had to contend and its relative inexperience in ball bearing manufacture.[1]

V. Importation of Ball Bearings.

(*a*) Disadvantages of Importation.

Reliance upon importation to meet a considerable portion of the demand was a matter of necessity, not of choice. Besides depending largely on the pre-war sources of supply in Sweden and Switzerland, the branch was obliged to develop a new source in America to meet the demands of the Mechanical Transport Department and the Aeronautical Department in 1917 and 1918. The disadvantages of this reliance on importation were, however, obvious. In the first place it involved considerable additional organisation. The export of the

[1] See Appendix XV. for statistics of progressive increase in home output.

raw material required to carry out orders placed with the Swedish and Swiss firms necessitated careful oversight to ensure that under cover of these requirements materials were not being taken out of the country for other purposes. Both the Foreign Office and the Admiralty required technical details as to the nature and use of every commodity to be exported before granting release, and thus the work of the branch was materially increased. Secondly, the transport difficulties were considerable, and delay and grave losses had always to be reckoned with. In October, 1916, the Skefko Company stated that during the preceding twelve months four consignments of ball bearings and components had been either sunk or captured by the enemy, involving a loss of 50,000 bearings and 500,000 steel balls. The branch therefore asked for special Admiralty protection for the cargo vessels, but this was not accorded until the loss of three more cargoes of supplies for the Aeronautical Department caused the latter to take action in April, 1917. Naval protection was then instituted, and losses in transit ceased.

A further difficulty, however, supervened in the blockade question. In the summer of 1917 the question of putting pressure on Sweden to stop her exports to Germany was raised by the Foreign Office. One of the possible results of such pressure would be to stop exports from Sweden to this country, and such a stoppage would vitally affect the ball-bearing position. The home supply at that date was totally inadequate to meet the demand, and the extensions to factories were all very much behind promises. In the last quarter of 1917 the Swedish supplies were equivalent to about 55 per cent. of the home supply. If the Swedish supply failed this amount must be provided either from home or other foreign sources. The probabilities of either of these being able to meet such an additional demand were exceedingly remote, and therefore the political situation was viewed with grave concern by the Ministry.

With regard to American supplies the disadvantage was chiefly a question of quality. There were a number of firms ready to undertake supply when the question was raised in October, 1916, but a strong prejudice existed among contractors in England against using American bearings on the ground of their unreliability. This prejudice was to some extent overcome as the result of experience, but the difficulty which then supervened was limitation in quantity, since the entry of America into the war automatically limited her ability to export munitions.

(*b*) Extent of Importation.

In spite of all these difficulties importation increased rather than decreased. The importation figures from Sweden and Switzerland are considerably larger in 1917 than in 1916, while at the same time we were receiving considerable supplies from America, a negligible source in 1916. The effect of the extension policy at home was scarcely visible in 1918, since the total percentage of imports from foreign

sources continued to increase.[1] But had the war continued, the extensions would have come into full operation in 1919 and a very considerable decrease in importation compared with home production would probably have ensued.

The supplies from the Svenska Kullager Fabriken (exclusive of the output of the Skefko Company) always ranked next in importance to those of the Hoffmann Company. In 1917 the aeronautical demand was so urgent that the possibility of purchasing the whole output of the factory was entertained, and arrangements were made to pay a premium on all deliveries in excess of 100,000 a month, working up if possible to 200,000 a month. As the estimate of aeronautical requirements was afterwards modified, the proposal to purchase the whole output was abandoned. The highest average of Swedish deliveries worked out at 104,000 bearings a month between November, 1917, and October, 1918. This does not, however, indicate the total amount of importation from the Company, since besides complete bearings they supplied practically all the steel balls and various other components for the Skefko factory. The monthly average of steel balls imported during the period June, 1917, to October, 1918, was 1,042,719.

The estimated monthly supply of bearings from the Schmidt Roost Company was 25,000, but in practice they fell very short of this number, their average monthly deliveries over the period October, 1916, to September, 1918, being only 16,000. This was in spite of the fact that heavy supplies of raw material and Hoffmann steel balls were being despatched to the firm, so in the summer of 1917 a member of the Ball Bearing Branch went over to investigate the position. He reported that the Company were fostering their French trade "at the expense of the urgent requirements of our own Government,"[2] and that they also supplied a considerable quantity of bearings in Switzerland for general trade purposes. It was pointed out to the firm that under the arrangement for supplying raw material the English Government was to have the first call on their full capacity, and that they must divert a larger proportion of their output to England. That the pressure brought to bear on the firm was at any rate temporarily successful is shown by the fact that supplies from this company increased to 19,000 per month for the last quarter of 1917, whereas before they had not exceeded 12,000 a month.

Importations from America may be divided into three classes :— (i) importations for orders placed by the Ministry ; (ii) importations by the Hoffmann Company ; (iii) importations by ball bearing traders.

Orders by the Ministry were chiefly for bearings for the Mechanical Transport Department and for the Aeronautical Department. The first experimental contract was placed in January, 1917, and was quickly followed by others, with the result that in March about 240,000 bearings were on order. As these proved fairly satisfactory on delivery, a series of further orders was placed, 95 per cent. of which were for aeronautical service. Until March, 1918, a continuous supply of

[1] See table on p. 89 below and Appendix XVI.
[2] Hist. Rec./H/1700/7, Appendix C.9.

high grade American bearings was received, and the importance of this source of supply was such that it was thought necessary to cable to the U.S.A. Government in June, 1917, urging them "to assist the Ministry of Munitions in the output of aeroplanes, motor transport and tanks by facilitating as far as possible the supply of ball bearings on order in the United States."[1] Owing to America's own needs, the supply gradually declined in 1918, but the average supply of bearings received from April, 1917, to October, 1918, was 50,000 a month.

The Hoffmann Company's imports consisted of magneto type bearings for high priority Government orders, chiefly aeronautical. The total imported was just over 100,000, and the course was adopted with the consent of the Ministry in order to allow Messrs. Hoffmann to concentrate on special bearings which were urgently needed.

Importation by traders consisted of lower grade bearings suited for general commercial purposes. These must have been imported during the whole period of the war, but no data of the amount of this importation were available till the Ball Bearings Order of November, 1917, made the submission of periodical returns of importation compulsory. From these returns it is reckoned that during the period November, 1917, to October, 1918, the monthly average of importation by traders was approximately 14,000. Adding this figure to that of Government importations, the total importation from America during this period may be placed at 64,000 a month at least.

VI. Results of the Work of the Branch.

In order to estimate to what extent the Ball Bearings Branch achieved the object for which it was created, the co-ordination of supply and demand, a series of comparisons should be made for each year of the war. Unfortunately, no data are available before October, 1916, the earliest figures being those furnished by the manufacturers in answer to inquiries which followed the ball bearing conference of July, 1916. Even these figures are not reliable, since the makers were unduly optimistic, and actual deliveries proved their July estimate to be decidedly too high. If the average of the actual deliveries for the last quarter of 1916 is taken, however, and compared with similar figures for 1917 and 1918 a broad indication of the increase in output can be obtained. The following table shows the relative output for these periods :—

	Home Supplies.		Imported (America excepted).		Total Supplies (America excepted).	
Period.	Average Monthly deliveries.	Percentage increase.	Average Monthly deliveries.	Percentage increase.	Average Monthly deliveries.	Percentage increase.
Oct.-Dec., 1916.	127,675	—	59,333	—	187,008	—
Oct.-Dec., 1917.	174,216	36·5	108,804	83·4	283,020	51·3
Sept.-Nov., 1918.	229,270	80	128,254	116·1	357,524	91

[1] HIST. REC./H/1700/7, Appendix B.10.

American supplies are not included because they are not known with any degree of accuracy for the 1916 and 1917 quarters. The figures of total supplies for the year November, 1917, to October, 1918, have, however, been worked out, and the average monthly deliveries from all sources for this period was nearly 373,000. Thus, compared with the last three months of 1916, supplies had practically doubled.[1]

The increase in supplies is, however, of little value unless the relative demand is also known. Here again the data are disappointing. Only two really comprehensive statements of requirements were drawn up, one for the report on the ball bearing situation of October, 1916, and one compiled ten months later as a basis for the allocation scheme introduced in August, 1917. For the period October, 1916, to April, 1917, the estimated requirements were 246,000 monthly; for August to December, 1917, 291,000. The following table shows the relation between supply and demand for these periods :—

Estimated Requirements.		Actual Supplies, exclusive of U.S.A.		Shortage.
Period.	Quantity.	Period.	Quantity.	Quantity.
Oct., 1916 to April, 1917	246,000	Oct. to Dec., 1916	187,000	59,000
		Jan. to Mar., 1917	201,000	45,000
1 Aug., 1917, to 31 Dec., 1917	291,000	July-Sept., 1917	250,000	41,000
		Oct.-Dec., 1917	283,000	8,000

The only figures of estimated requirements for 1918 are those of a memorandum placed before the Advisory Committee appointed in July, 1917. In this document the minimum requirements for 1918 are stated to be 423,000 a month, of which it was hoped that 367,000 could be obtained from home factories and the balance by importation. If this estimate of requirements remained valid it is obvious that the shortage, which was steadily decreasing in 1916 and 1917, rose again with a jump in 1918, since the average monthly deliveries from all sources during 1918 hardly reached 373,000.[2] It is probable, however, that at some time later than July, 1917, requirements were revised on a downward scale, and the deficiency was really less than the 50,000 a month indicated. No figures have so far been found to prove this, but it is supported by the fact that in 1918 the departmental clamour for supplies diminished very considerably, though the effect of the allocation scheme introduced in August, 1917, must also be taken into account. But from the figures available, it does not seem that supply had actually overtaken demand at the date of the Armistice, though the outlook for 1919 was promising.

[1] Appendix XVI. [2] *Ibid.*

In addition to meeting the problem resulting from war conditions, the activity of the Ball Bearings Branch has resulted in the creation of new assets for post-war industry. The extension of the existing factories and the erection of the new Rudge Whitworth factory will make it possible to meet the demand for ball bearings from home sources far more completely than before the war. The capacity of English factories was increased by over 80 per cent. between 1916 and 1918, and, with the shrinking of the demand to its normal dimensions, this increased capacity will be able to take up that part of it formerly met by importation. Thus, as in the case of gauges, new possibilities of employment and extended industry have been opened up for the future, possibilities which are all the more valuable because of the greatly increased use of ball bearings which the experience of war production foreshadows.

CHAPTER IV.

ELECTRIC POWER SUPPLY.[1]

I. Administrative Policy.

" Cheap and general power supply . . . . . goes to the root of all industrial prosperity . . . . . For all efficient factories motive power means electricity."[2] This is now regarded as an axiom of modern industry, applying not merely to emergency production, but to normal industrial organisation. So rapidly has opinion moved within the last five years that it is astonishing to find that only the most far sighted business men appreciated the full value of electric power at the outbreak of war. The majority of factories were still run on steam power, and though all manufacturers realised at once the necessity for a rapid extension of output in munition industries, only a minority appreciated the corresponding necessity for greatly increased supplies of electric power. This lack of insight had important results, both locally and centrally.

There are signs that locally, in certain areas at any rate, a restrictive rather than an expansive policy was adopted. The Yorkshire Electric Power Company closed down all extensions and capital expenditure from August, 1914, to the middle of 1915. The Town Clerk of Bradford, in an application for Government assistance for extensions in January, 1916, stated that, " from the commencement of the war up till the end of March, 1915, the number of applications for supplies of electricity was much below the average, as was the aggregate amount of energy demanded in connection with such applications." This reactionary attitude was not confined to the consumers ; the Corporation and the Local Government Board followed in their wake. Before the outbreak of war, the raising of a loan to cover the cost of installing a suction ash plant at Bradford had been sanctioned by the Local Government Board, but in March, 1915, one of the Board's Inspectors advocated deferring the installation. The Corporation fell in with this view, with the result that when the demand for increased power supply came, the Corporation was absolutely unable to meet it, and hand to mouth arrangements had to be made, with the resulting disadvantages of extravagance, insufficiency and delay.

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[1] See Hist. Rec./R/1380/1-11; Hist. Rec./H/1380-1; C.R.V/S/419, C.R./4382; Memorandum of Council Committee on Demobilisation and Reconstruction, Serial No. 122; Article in *Journal of Institution of Electrical Engineers* for May, 1919.

[2] Hist. Rec./R/1380/1.

The failure to appreciate the potentialities of electric power in production resulted also in a lack of provision for administrative control from the centre. When the Ministry of Munitions was established, no administrative machinery was set up to deal with this question. The Department of Gun Ammunition soon found, however, that one of the factors conditioning shell production was the supply of power, and that the laws of supply and demand being for the time in abeyance, some action must be taken to ensure that production and distribution should be adequate to meet the munitions demand.

(*a*) Electrical Engineer attached to Gun Ammunition Department, July, 1915.

An experienced electrical engineer (Capt. McLellan) was appointed in July, 1915, to advise the department on all questions of power supply whether for the new national factories or for private contractors, in so far as the latter consulted the Ministry in their difficulties. This organisation was not, however, satisfactory. The question of power supply was too large a one to be properly treated as an adjunct of a department whose primary interest was shell production, while in the summer of 1915 the demand was already so urgent that there was no time to survey the field as a whole and plan a balanced comprehensive scheme of supply. The result was that the early efforts of the Ministry to meet the power problem were marked by a lack of concerted policy. Existing power stations were extended with little regard to their efficiency and post-war adaptability, and many new factories were equipped with private stations at considerable cost, whereas a more considered policy would have led to the supply being taken from existing sources. The result of these hastily improvised measures was chaos, inefficiency, and extravagance. The weakness of the position was fully recognised by Capt. McLellan, but the urgency of supply at this time was so great that ultimate desirability had to give way to immediate necessity.

As soon as possible, however, a definite principle of supply was enunciated. All consumers, whether Government enterprises or private organisations, should obtain their power from existing stations rather than generate it separately in private stations attached to their factories. Thus concentration in large units of production rather than dissemination in small ones would be promoted, with the immediate advantages of economy in labour, plant and materials, and the ultimate possibility of incorporating these units into any large scheme of electric power supply which might be promoted after the war. It was not desirable or possible to pursue this policy rigidly. In factories where waste heat could be utilised it was more economical to include a power station in the lay-out of the factory than to buy current from a public service undertaking. On the other hand, stations in the neighbourhood of new factories did not always exist, and a private power house had therefore to be built. But in large areas where there were existing facilities they were utilised : for instance at Sheffield, where there were several national factories, supplies of

power were obtained from the Sheffield Corporation, which carried out large extensions to meet the demand. As time went on and organisation in general improved, the exceptions to the general principle became fewer. The possibility of purchasing power from a local supply station was considered as one of the factors in choice of site for new enterprises, and Government sanction to erect private power stations was more and more sparingly given. Thus a progressive application of the principle took place, and when the Department of Electric Power Supply was instituted in June, 1916, it may be said to have inherited the principle as the charter of its foundation.

(*b*) Formation of Electric Power Supply Department, June, 1916.

The increasing amount of work involved in the carrying out of this administrative policy was the cause of the reorganisation which resulted in the establishment of the separate Department of Electric Power Supply. Capt. McLellan was appointed Director, and remained in charge of the department till August, 1917, when he was transferred to the Admiralty, and Mr. A. B. Gridley was appointed Director in his stead. Under his control, the department steadily put into practice the principle evolved under Capt. McLellan, directing the work of extending stations to meet the demand, helping the supply authorities to obtain financial assistance where necessary, and co-ordinating the requirements of the supply departments within the Ministry. Thus the existing demands of the supply departments, together with the possible sources of supply, all came within the purview of one central authority, whose knowledge of the whole industry enabled it to prevent overlapping and conflicting orders being given, to indicate a source of supply which would be both economical and efficient, and to organise an ordered and balanced system of supply in place of the *ad hoc* arrangements which earlier necessity had forced upon the Ministry.

(*c*) Appointment of Electrical Services Sub-Committee, September, 1918.

Though the Ministry solved its own problem to a large extent in 1916, it was hampered in applying its principles by the conflicting requirements of other Government Departments. The Ministry was by far the largest user of electricity, but the War Office, the Admiralty, and the Air Ministry all required supplies, while the conditions of supply for civil purposes were laid down by the Board of Trade and the Local Government Board. It was therefore found necessary to extend the principle of central administrative control established in the Ministry in order to bring about co-operation between the different Government Departments. As early as November, 1917, the Director of Electric Power Supply pointed out how the independent action of the other Departments tended to neutralise the efforts of the Ministry to obtain efficiency and economy. As an example he quoted the case of a repair factory at Battersea, which was being established in connection

with the A.S.C. under the ægis of the War Office. It was proposed to equip the factory with private generating plant, but investigation by the Electric Power Supply Department had shown that it was possible and far more economical to buy the current required from the Battersea power station. In spite of these representations, nothing was done to effect co-ordination at this time, but by the middle of 1918 conflicting Departmental requirements for most basic supplies had become so numerous that the War Cabinet War Priorities Committee was set up to consider the question from an impartial standpoint. This Committee appointed the Electrical Services Sub-Committee, consisting of representatives of all the Departments concerned under the Chairmanship of the Director of the Electric Power Supply Department. The work of this Sub-Committee was practically to review the whole field of supply and demand in order to secure uniformity of policy with regard to contracts and extensions, uniformity of practice in the use of electrical energy, and equilibrium between demand and supply both in the matter of power and electrical apparatus. This work included the approval of all applications for generating plant, either from Government Departments or any other source, and the recommendation of priority grading for power supply contracts between Government Departments and power supply undertakings. In this way it was hoped to eliminate the competition between Government Departments by allocating supply in accordance with the urgency of demand, and to save power companies and electrical firms the difficulty of deciding between competing Government orders. To a great extent the Committee succeeded in achieving its objects, and its work proved that it would have been of considerably more value had it been formed earlier in the history of the Ministry.

II. Extension and Control of Supply.

(*a*) Extension of Sources of Supply.

As the administrative principle of concentration of supply became more widely applied, the demand on the existing sources became correspondingly heavier, and the necessity for extensions became obvious. Existing stations were of four kinds :—

(1) Light and power stations carried on by Local Government Authorities, either Corporations or District Councils.

(2) Light and power stations carried on as a business undertaking by a company.

(3) Railway and tramway power stations.

(4) Private stations.

As sources of supply the two last were negligible, being either unsuitable for extension or fully occupied with supplying the demands of their own services. The Ministry therefore concentrated on encouraging the extension of municipal stations and company stations. The difficulties in the way were considerable. All electric supply authorities, whether municipal or private, are limited by the Electric

Lighting Acts of 1882, 1888 and 1909, laws which, in the words of the Board of Trade Committee on Electric Power Supply, are "unsuited to the present times." Besides this handicap, most of the supply authorities suffer from a lack of capital, since electric light undertakings involve heavy capital expenditure, and returns are a long time coming in. Company undertakings which had a reserve capital were therefore few, while municipal authorities were dependent for all large schemes on loans raised under rules laid down by the Local Government Board. It was, therefore, obvious that if the Ministry were to carry out its policy, it must be prepared to find money to finance extensions.

The question was definitely raised in September, 1915, when the Sheffield and Coventry Corporations applied for assistance towards extending their electricity works in order to meet the additional demands resulting from the munition output in their areas. As these were evidently but the forerunners of similar requests, it was considered that a general policy should be adopted with regard to them all, and the Ministry, the Treasury, and the Local Government Board in consultation drew up a scheme to serve as a basis for financial agreements with local authorities. The capital required for extension was to be lent by the Ministry at $4\frac{3}{4}$ per cent. interest for the periods usually allowed for loans for similar works by the Local Government Board. If during the period of the loan the plant was found to be more than was required for the public service of the area, the Ministry was either to take over the plant at the amount of the debt outstanding, less any profit resulting to the local authority from the installation of the plant, or write off so much of the debt outstanding as would prevent any loss to the local authority in respect of the plant. Any matters arising out of the agreement were to be settled by the Local Government Board under Section 62 of the Housing and Town Planning Act of 1909.

On the basis of this scheme the Ministry began negotiations with the Coventry and Sheffield Corporations. As, before the details of the general scheme had been settled by the Government Departments, the Ministry had mentioned $4\frac{1}{2}$ per cent. as the rate of interest to these two Corporations, proposals were made on this basis, though the Treasury intimated that they would only accept this rate owing to the peculiar circumstances and that it must not be considered as establishing a precedent. The Coventry Corporation accepted the proposals without any demur, and an agreement was made on 29 September, 1915.[1] In December the agreement was extended to cover a further loan of £30,278, but the rate of interest was $4\frac{3}{4}$ per cent. instead of $4\frac{1}{2}$ per cent. The Sheffield Corporation proved less easy to deal with, as they considered that the rate of $4\frac{1}{2}$ per cent. was excessive. As, however, the Treasury firmly declined to make any further concession, the Corporation had to give way on this point. As an alternative, however, they inserted in the heads of agreement several stipulations with which the Ministry and the Treasury were not prepared to agree. Negotiations were therefore still further

[1] The actual text of the agreement has not been found.

protracted, and it was not till January, 1916, that terms were finally arranged. Under the agreement the Corporation was to finish the extension of the Neepsend Electric Power Station, already begun under arrangement with the Local Government Board, and equip it with the necessary machinery and plant, mains and cables. The cost of the building and the equipment originally designed for it was to be borne by the Corporation, but for all the additional machinery, mains, and cables, which had become necessary owing to the increased munitions demand, and which the Corporation estimated would involve a capital outlay of approximately £160,000, the Ministry was to advance money at 4½ per cent. interest. In addition the Ministry agreed to pay any additional cost incurred by the Corporation in pushing forward the work at the highest possible speed up to a sum of £7,500. At any time the Ministry was to have the option either of removing the equipment for which they had advanced money (subject to 12 months' notice in writing) or of requiring the Corporation to buy it at its fair market value at the time of purchase. The Corporation might at any time pay off any debt outstanding under the agreement after giving six months' notice.

In February, 1916, the Sheffield Corporation applied for another loan of £137,000 to cover the installation of further machinery, on the same terms as in the existing agreement. They based this request on the additional demands for current amounting to 14,700 kilowatts from the big munitions firms of Sheffield. Prominent among the applicants were the two National Projectile Factories, Messrs. Hadfield and Messrs. Kayser, Ellison & Co. Such a demand could not be met even when the extensions already agreed to were giving a full supply of power, and in addition there was the necessity of keeping a safe margin of power in case of emergencies. The Ministry, however, considered that the new application could not be regarded in the same light as the earlier one, since the first extension was pressed upon the Corporation to provide chiefly for the large new demand of the national factories, and urgency was the chief factor in the situation. The proposed new plant was to provide for expansion of requirements, not additional ones, and would not be available before 1917. It was thought that the Corporation ought to take the responsibility for providing plant to meet the growth of demand, and therefore the Treasury agreed with the Ministry in refusing to make special terms, and the Corporation was informed that the usual procedure of a loan raised under the sanction of the Local Government Board should be adopted.

In February, 1916, an application was received from the Bradford Corporation for a loan of £98,965 to provide for an extension of their electric power station. The Corporation wished to make an agreement on the basis of the model Treasury agreement, but the Ministry considered that it did not apply entirely to the Bradford case, since it had been drawn up to meet cases where extension was directly necessitated by output of munitions. In the Bradford area there was a large amount of textile work as well as munition work, and it was impossible to separate the demands of the non-munition trades

on the power station from those of the munition trades. At the same time it was not desirable, "from the point of view of the efficient conduct of the war,"[1] to refuse the Corporation any assistance at all. The estimated cost of £98,965 was therefore split up into two parts, £49,515, covering the extension of the boiler house and cooling tower equipment, which was the most urgent part of the work, and £49,450 for the remainder of the extensions. In a letter to the Treasury the Ministry pointed out that there was an argument for assistance in respect of this sum also, namely, that "power can be provided more economically . . . from a Central Power Station than from a number of private power plants," and that "the resulting economy of production is of undoubted value from the point of view of industrial output in an important export trade." But they did not press the point, and the Treasury only sanctioned a loan of £49,515, saying that they thought the rest of the scheme should be abandoned, because of "the strong objection to capital expenditure at the present time, to which no exception can be admitted save for the sole purpose of an immediate expansion of munitions output."[2]

Loans were granted to many other Corporations besides Sheffield, Coventry and Bradford. The Sheffield agreement may, however, be considered as typical, except that the rate of interest was $4\frac{3}{4}$ per cent. instead of $4\frac{1}{2}$ per cent., and in many later agreements the stipulation appears that the Corporation shall not make any connections to their mains for supplying electricity for any purpose other than munitions making except with the express consent of the Ministry.

Financial assistance to company undertakings could not be given on the uniform lines arranged for local authorities, since the circumstances of the cases differed widely and individual treatment was therefore desirable. The broad principle adopted was that where a company could show that the increased demands on its power supply were the result of expanded munition industries, favourable consideration should be given to the proposals made by the company for Government help. As far as possible the efficiency and the ultimate value of the power station in a national system of power supply were taken into account in granting financial assistance. But it was not always possible to refuse help to badly managed or badly situated power stations, and undoubtedly many power stations were extended on account of immediate necessity which would not fit in satisfactorily to a future national system.

The terms on which assistance was granted varied considerably. A typical example is the loan granted to the Yorkshire Electric Power Company in February, 1916. The company pointed out that the demand of munition firms in the area supplied from their power station had increased abnormally since the spring of 1915, while they had been unable to increase their plant to a sufficient extent to keep pace with the demand owing to lack of reserve capital. The result was that their generating plant was loaded up to the fullest extent. Owing

[1] HIST. REC./R/1380/3.
[2] HIST. REC./R/1380/3. Treasury letter of 14 March, 1916.

to the strain to which it was subjected there was constant danger of breakdowns, and new demands were coming forward which there was no possibility of meeting without the installation of new plant. It was impossible at that date to raise new capital through the usual channels, and therefore the company asked for a Government loan to meet the necessary outlay, which they estimated at £60,000. The security for the loan was to be the new plant, interest was to be at the rate of 5 per cent., and repayment was to be made in equal annual instalments in the four years following the termination of the war or earlier if the company so desired. The Ministry approved the proposal, and sanction having been obtained from the Treasury, the loan was granted on these terms.

An agreement of another type was proposed by the Clyde Valley Electrical Power Company. The demands for electrical power in the Clyde district were, by February, 1916, overtaxing the capacity of the company's two existing stations, and the erection of a third station was an urgent necessity. The company realised that this expenditure would normally have become necessary in about three years' time; but, as they pointed out, they were now being compelled to undertake it under the worst possible conditions, and the cost would be at least 50 per cent. more than under pre-war conditions, while at the end of the war the value of the station would fall by at least an equal amount. In view of the fact that the company's ordinary shareholders had received no interest on their shares during the 14 years the company had been in existence, the Directors did not feel justified in undertaking the expenditure involved unconditionally. They therefore asked the Ministry to sanction the treating of the sum of £25,000, which they estimated would be the increase on the capital cost due to war conditions, as depreciation spread over a period of three years in all questions of taxation, and that the income tax and the excess profits tax should be adjusted on these lines. Though this proposal suited the circumstances of the Clyde Valley Company, the difficulty of applying it as a general principle was that few of the electrical undertakings made excess profits. In utilising it therefore as a basis of agreement with other firms it was modified slightly, and the same object was obtained by guaranteeing to companies the difference between the war costs of carrying out extensions and the estimated cost of the same work at periods which varied from one to five years after the conclusion of peace.

One or other of these plans was usually adopted in dealing with requests for financial assistance. A few power companies asked for definite grants towards the excess cost of war extensions, but it was generally considered fair that electric supply undertakings enjoying a monoply and supplying a commodity for which there would be a large post-war demand should not be entitled to assistance to the same extent as manufacturing firms called upon to extend their factories and manufacture products for which there was normally but little demand. It is estimated that the extension of power houses and mains during the war involved a sum of £23,000,000, and of this about £3,150,000 was advanced by the Ministry of Munitions. The measures taken

during the winter of 1915-16 apparently met the immediate demand. But by the end of the year it became obvious that in certain areas further extensive provision must be made if demands which would materialise in 1917 and 1918 were to be met. In Sheffield and Birmingham especially applications for new connections were very heavy, and both Corporations therefore laid before the Ministry schemes for the erection of large new stations. These stations would be finished by the middle of 1918, and would be ready to take up the demands which, as the Corporations pointed out, would require immediate satisfaction if the war was still in progress, while if the war were over by this date they would be of the utmost value in helping to meet the heavy post-war demands for materials and manufactures of every kind. In view of the fact that these proposals were for future rather than immediate needs, it was felt by the Ministry that a question of policy was involved, and they were therefore referred by the Ministry to the Advisory Council. The Council decided that, in view of the existing shortage of raw material and labour, the Ministry ought not to use its powers to push forward schemes which would not materialise for a considerable time and which, it was hoped, would have a post-war rather than a war value. Accordingly the Corporations were informed that the Ministry could offer them no assistance, and they must proceed with their plans by the usual methods of Parliamentary legislation and negotiation with the Local Government Board. Apparently this was done by the Sheffield Corporation, since the proposed Blackburn Meadows station figures in a scheme for linking up with the Rotherham Corporation works carried out in 1917. The Birmingham Corporation seems to have dropped its scheme for a time, but it was revived again in 1918 in connection with a plan to link up with the Shropshire, Worcestershire and Staffordshire Power Company.

The logical development of concentration of supply in existing public service undertakings was the connecting up of stations situated near to one another and with similar plant equipment in order to obtain still larger units of supply. This was the policy advocated by the various committees reporting on the development of a national system of power supply after the war, and the immediate advantages to be gained were greater economy of labour and materials and less danger of failure of supply through breakdowns of generating machinery. This question of reserve power became very important as the demand increased and the difficulties of extension became greater. Many of the smaller power stations were working almost up to the limit of their power capacity, and if a breakdown occurred complete stoppage was the result. By connecting such stations with other stations a transfer of the load was made possible at a crisis and the possibilities of delaying output were minimised. For this reason specially the Electric Power Supply Department pressed the policy of linking up suitable stations in large munition areas wherever possible. The most successful example of this scheme was to be found at Rotherham. Early in the war the Rotherham Corporation extended their power station and equipped it with new plant on the most modern

lines. The machines, which consisted of two 12,500 kilowatt sets and one 25,000 set, were the largest in any generating station in Great Britain. In order to get the full value out of this plant, it was arranged that the station should be linked up with the new Blackburn Meadows Station of the Sheffield Corporation, so that 10,000 kilowatts could be transmitted either way. In November, 1917, the idea was brought forward of extending this scheme by linking up also the Yorkshire Electric Power Company's area, the South Yorkshire coalfield and the Lincolnshire ironstone area, covering in all 1,250 square miles. A committee of those interested was appointed to make proposals, and they recommended the construction of new power houses on the river Trent for the service of the whole area. No action was taken on the report, however, since obviously the scheme involved other than war considerations, and therefore must await post-war legislation covering the whole question of power supply.

It was not always easy, however, to carry out even purely war schemes, owing to difficulties experienced with the local authorities or with the Treasury. A proposal for co-operation between the British Cellulose Company and the Derby Corporation came to grief because, instead of accepting the Ministry's suggestion that similar generating sets of 6,000 kilowatt capacity should be installed by both, the Company wished to instal two 10,000 kilowatt sets in its own power house and sell current to the Derby Corporation. Though this was sound engineering policy, the susceptibilities of the Derby Corporation were offended, and in so far as the Company's proposal turned a scheme for interdependence into one of dependence of one body on the other, it ran counter to the idea of co-operation. The whole scheme was therefore dropped and each station carried on supply individually.[1]

A plan which had to be abandoned owing to financial difficulties was the establishment of a joint power supply by the Birmingham Corporation and the Shropshire, Worcestershire, and Staffordshire Electric Power Company. In January, 1918, it was proposed that a new power house should be built at Nechells containing two 15,000 kilowatt turbo-alternators, and another on the Severn at Stourport containing three similar machines. The estimated cost of the scheme was £2,750,000, and it was hoped that the entire enterprise would be completed in 21 months' time. The initiators of the scheme proposed that the Ministry should find the capital and that the Corporation and company should jointly establish a Generating Authority to work the power houses and pay an annual rent at the rate of 7 per cent. to the Ministry. The scheme was approved by the Electric Power Supply Department because both authorities were already working at their maximum load, their existing plants were in serious need of overhauling and repair, and urgent war applications for further power

[1] It appears that later the Director of Electric Power Supply modified his view, because of the soundness of the British Cellulose Company's schemes, and supported their proposition. But since urgency was the first consideration, and modification of arrangements would curtail delay, the original scheme was adhered to.

were awaiting fulfilment in both areas. It was therefore inevitable that extensions should be made by each authority, and it was much more economical for present purposes and more in line with future developments that a joint scheme should be undertaken. The scheme was endorsed by the General Services Committee of the War Priorities Committee and by the Munitions Council Co-ordinating Committee in March, 1918, but the Treasury, supported by the Board of Trade, refused to sanction it on the ground that it was not a war measure and therefore did not fall within the scope of the Ministry Vote of Credit. The Treasury considered that the action to be taken "at the moment" was to instal "the minimum plant necessary to satisfy the demand for munitions purposes in the Birmingham district in the shape of generating units of comparatively small size (5,000 to 6,000 kw.), which it would appear can be provided more readily than the larger sets and at a considerably lower initial cost." As regards the Stourport part of the scheme, it could "await consideration as part of the general problem of the reorganisation of power supply."[1] This attitude was strongly deprecated by the Director of the Electric Power Supply Department, who pointed out that, though the smaller additional provision of capacity would cover the absolute minimum stand-by requirements, a compromise of this kind would be "indefensible from the standpoint of permanent development, since it would perpetuate an inefficient system of supply and would make it impossible to utilise the available sites in an economical fashion."[2] As, however, the Treasury remained obdurate and the difficulty of getting a special Vote of Credit in Parliament seemed insuperable, the full scheme was abandoned.

(*b*) Control of Supply.

Though the most significant part of the department's activity was its extension policy, its work in controlling distribution of power and supplies of electrical equipment was by no means unimportant. At first control of equipment was adequately secured by the priority system. No certificates were issued to applicants for electrical plant without the approval of the department, and all electrical manufacturing firms had to submit their orders and obtain confirmation of their priority certificates before manufacture could proceed. Thus grading according to urgency was secured, and work other than essential war work was eliminated. A check on the distribution of power was obtained by the submission of electrical supply undertakings' schemes to the department for approval. This system worked satisfactorily till 1918, when the necessity for cutting down plant requirements to the absolute minimum, and economising in the use of power because of the coal situation, led to the establishment of a more rigid system of control.

The first order issued was the Converter Plant Control Order in April, 1918.[3] It was found that many firms, especially shipbuilding

[1] Council Committee on Demobilisation and Reconstruction, Serial No. 122.
[2] *Ibid.*
[3] Appendix XVIII.

firms, were demanding supplies of direct current from public service undertakings where alternating current was being generated. Though this was equally suitable for power purposes, no amount of persuasion would induce many consumers to use it, and money, material, and labour were being widely wasted in installing converting plant. The refusal of the Ministry to issue licences for converter plant in such cases strengthened the hands of the engineers of power stations in dealing with conservative consumers and convinced these by experience of the equal value of alternating current for power purposes.

The critical position of the coal supply rendered restrictions on the use of electric power absolutely indispensable in 1918. In July the Coal Controller suggested the possibility of rationing electric power stations as regards supplies of coal. But this course was strongly opposed by the Electric Power Supply Department, which pointed out that the consumption of coal by public service undertakings only had increased by 1,000,000 tons during 1917 and 1918, and would, it was estimated, need to be increased by a further 1,000,000 tons in 1918 and 1919 if the demands of the munitions firms for electric power were to be met. The right course to adopt was not to ration electric power supply undertakings, but to restrict the use of electricity for other than urgent war purposes by forbidding the making of new connections. A Council Committee of the Ministry was appointed to consider the position, and they recommended that Regulation 11a of the Defence of the Realm Act should be amended to cover electricity, and a control order should then be issued. They considered that the order should be widely framed, and besides prohibiting new connections should give the Ministry power to order certain classes of consumers to cease using current during certain hours of the day, to close down unnecessary power stations, and to order the interlinking of power stations and the sale and purchase of current to or from interlinked stations. The practical difficulty of devising machinery to carry out the last recommendation and the possibility of industrial disturbance involved in the first caused these recommendations to be dropped, and when the Electricity (Restriction of New Supply) Order was issued in November, 1918, it was confined to restricting the connection of new consumers to power stations to those wholly engaged upon the production of urgently needed munitions.[1]

The necessity for enforcing this Order to any great extent was avoided by the signing of the Armistice. In January, 1919, the Order was revoked, and in February the Converter Plant Control Order followed it into oblivion. In the matter of electrical supply, control was therefore practically confined to priority grading, and even here certificates were granted with considerable freedom until the increasing shortage of labour and materials made greater restrictions inevitable. In adopting this policy the department was guided by the consideration that electrical supply undertakings were doing their best to give an urgently needed supply under circumstances of considerable difficulty, and that restrictions would only hamper their activity and discourage their efforts.

[1] Appendix XIX.

(*c*) Advisory Functions of the Department.

In the course of its work of extending supply and controlling distribution, the Electric Power Supply Department was called upon to advise, not merely other departments of the Ministry, but also the War Office, the Admiralty, and the Air Ministry. At first the other Government Departments carried out their schemes and placed their orders independently. But as soon as demand outdistanced supply, this procedure was bound to lead to conflict at the centre, and irritation and unequal burdens locally. Accordingly it was arranged that all Supply Departments, both Ministry and otherwise, should consult the Electric Power Supply Department on all schemes where the installation of electric generating plant or the purchase of current from a public service undertaking was concerned. Schemes for Admiralty shipyard extensions involving the use of electric power were also placed before it. On the financial side it assisted the Local Government Board and the Scottish Office by advising on the technical aspect of municipal applications to borrow money for electrical extensions.

(*d*) Supplies to Allies.

Advice on the requirements of Allied countries also formed part of the department's work, and in the case of Russia, it had also to undertake a good deal of the responsibility for supply. In the earlier part of the war, the Russian Government and Russian firms were large buyers of electrical machinery and apparatus from Great Britain. Much of this plant appears to have been ordered without any co-ordinated plan, and this, combined with the sinking of some most important cargoes of power station equipment, made it a difficult matter to meet the Russian demands effectively. When Russia withdrew from the war there was a great deal of plant still in various stages of manufacture for her. As far as possible orders were cancelled, but it was better policy to complete some of it and adapt it to British requirements. At the date of the Armistice, however, a great deal of it still remained in hand.

A certain amount of help was also given to America to erect generating stations at the American bases in France. The department sent engineers to France to consult with the American authorities and much of the plant was supplied from England.

III. Increased use of Electricity during the War.

(*a*) Developments in Industry.

A survey of the developments in the electrical industry during the war indicates its possibilities as one of the most potent forces in the industrial world. Both the quantity of power demanded and the new uses to which it was put prove its significance as a factor in rapid and economical output. The most interesting and important development was the adoption of electrical furnaces for producing steel, particularly in the Sheffield district and at Woolwich Arsenal. Before the war a

large percentage of Sheffield's tool and other steel was produced by smelting a high grade ore imported from Sweden. At the outbreak of war these ores were diverted to Germany, and English steel makers had to supply the deficiency from other sources. Experiment showed that the same class of steel could be produced from scrap metal, and from iron and steel obtained from home and Spanish ores, by means of electrical furnaces. So successful was this treatment that in 1918 there were 117 furnaces in existence (74 were situated in Yorkshire), very few of which had been installed before the war.

Under Lord Pirrie's régime as Controller of Merchant Shipbuilding at the Admiralty, there was a large development in the use of electrically driven compressors in shipyards. Lord Pirrie thought that the installation of these compressors, with which very few of the shipyards were as yet furnished, was the key to more rapid shipbuilding construction, and about 80 compressors were put in hand for various shipbuilding centres. Another device for hastening shipbuilding was the use of electricity for welding ships' plates. This was, however, only in the experimental stage at the end of 1918.

Schemes were also set on foot for an improved type of electric regenerator for the testing of aeroplane engines which could be used with alternating current instead of direct current. It was estimated that this new equipment would effect such economy as to pay for itself within a few years. Unfortunately the time that must elapse before the new plant could be manufactured, the doubt as to the future policy of the Air Board, and the conservatism of manufacturers, all combined to discourage an active forward policy, and when the Armistice was signed the idea was dropped, though it would appear to be of as great value in normal industry as in war time production.

(*b*) EXPANSION OF ELECTRIC POWER SUPPLY.

The remarkable acceleration of output during the war can only be realised by examining the statistics for the period 1914 to 1918. One hundred and forty-six stations were either extended or built,[1] and many stations which did not extend their buildings increased their plant. In June, 1914, the plant capacity of 557 municipal and company stations was 1,135,000 kilowatts ; in November, 1918, it was 2,278,000, having thus doubled itself during the four years.[2] As individual examples of expansion Sheffield and Rotherham may be instanced. Sheffield's plant capacity in 1914 was 23,000 kilowatts, in 1918 it was 96,000. Rotherham is even more remarkable. From 5,000 kilowatts the capacity of the Corporation station rose to 70,000, an increase of 1,300 per cent. Not only was the total capacity of the plant affected, the size of the generating unit also increased. The average size of the unit installed before the war was 522 kilowatts, and the largest unit in operation was 8,000 kilowatts. At the end of the war the average size was 7,000 kilowatts, and units as large as 25,000 and 30,000 kilowatts were being built. Output rose to correspond with the increase in

[1] Appendix XVII. [2] *Ibid.*

capacity. During the year ending June, 1914, the units sold were 2,100,000. For the year 1917 they were 3,520,000, and though actual data were not available, it was estimated by the Electric Power Supply Department that the 1918 output was nearly double that of 1914. Sheffield alone increased its output about $6\frac{1}{2}$ times; in 1914 the units sold were 26,500,000, in 1918 177,500,000. This increased output was obtained side by side with a decreased consumption of coal. The coal consumption per unit was in 1914 4·1 lb.; in 1918 it was only 3·75 lb., in spite of the relative inferiority of the fuel at that date. This was due largely to the more efficient plant, the improved load factor of many power stations, and the extended use of oil fuel, waste heat and gas and water power for generative purposes. During the years 1914 to 1918, 288,000,000 units were obtained by these means.

The great interest of the organisation of the electric power supply during the war lies in its relation to post-war conditions. Unlike much of the industrial development promoted by the Government during the war, its value has not decreased with the return to peace conditions. The policy of centralisation of power production advocated unanimously by the committees appointed to consider the part to be played by electric power in reconstruction is to be found in germ in the practice of the Ministry, and experience of war production has proved that only in this way can the generation of electricity be undertaken at a reasonable cost and in sufficient quantities for it to be available throughout the country as the normal motive power in industry. Not only has the experience of the Ministry been of value to the State as the starting point of a scheme for the general application of electric power to industrial conditions; the leaders of industry themselves are following in its steps in advocating the use of electric power on co-operative principles. A noteworthy instance of this is that the Yorkshire and Lincolnshire centralised power supply scheme brought forward by the Ministry in 1917 is now being seriously considered by the industrial organisations of the area with a view to taking action when the necessary legislation has been passed. This is but a forerunner of many similar schemes, and even if a national scheme of electric power supply does not become an accomplished fact, industry as a whole has been so convincingly shown by Government enterprise the value of electricity in accelerating and cheapening production that development along these lines will be an essential part of the industrial organisation of the future.

APPENDICES.

APPENDIX I.

(CHAPTER I., p. 17.)

Specimen Authorisation to Contractor to Put Work in Hand.

Armament Buildings,
Whitehall Place,
London, S W.

Sir,

GAUGE ORDER.

You are authorised to put in hand immediately the gauges enumerated on the attached list.

The gauges must be delivered to the order of :—

D.G.M.S., c/o Director,
National Physical Laboratory,
Teddington, Middlesex.

It is desirable that the first gauge of every pattern should be sent to the laboratory to be tested before the order is completed.

Arrangements have been made with the N.P.L. to secure their assistance in the checking of the gauges, and it is suggested that you would be well advised to have check gauges, and such fundamental length standards as you may require to use in the manufacture of the gauges, standardised at the laboratory before completing your work.

Material should be tool or high grade steel, with hardened working surfaces ; screw gauges, with certain exceptions, need not be hardened.

Every gauge must be marked, in accordance with the list attached, with the following particulars :—

Description of parts to be gauged.

Dimensions of gauging parts.

Identification or I.L.S. Number.

Initials of Contractor.

Serial Number.

Date (month and year only).

Note.—Each gauge must be stamped with a different serial number ; if the series allotted is 51 W. to 100 W. the first gauge of the order will be marked 51 W., the second 52 W., and so on, to the end of the series.

In flat gauges the shapes may be altered provided the gauging dimensions on the drawings are adhered to.

Four small holes may be drilled for punching so as to machine several at one time, also small clearance holes may be drilled in corners to facilitate grinding.

Female, cylindrical and screw gauges having two gauges in the one piece of metal may be fitted with steel bushes driven in and finished to size if preferred.

The contract and official order for this work will follow in due course; material, however, should be ordered and work put in hand at once.

Official working drawings will be supplied by the Chief Inspector, Woolwich.

I am, Sirs,

Your obedient Servant,

SCHEDULE.

Gauge Order Number	G.O. 370.
Class of Gauge.	Inspection
Gauges required for	Cartridge Q.F. 18-pounder Mk. I and II.
Drawing No. of Gauges.	C.I.W. 2038

Delivery, 8 weeks from date of receipt of official working drawings.

Quantities and types required :—

100 Gauges I.L.S. 272 C. Screw Gauge, Primer Hole (to be hardened).

Gauges to be stamped as follows :—

Identification No. Initials. Serial Nos.

APPENDIX II.

(CHAPTER I., p. 22.)

Illustrations of Downward Tendency of Prices.

Type of Gauge.	*Date of Contract.*	*No. ordered.*	*Contractor.*	*Price per Gauge.* £	s.	d.
Shell 8in. How. 981D.	28.3.16	25 ..	Horstmann Cars, Ltd.	4	0	0
	2.6.16	12 ..	Flottmann Eng. Co.	3	17	6
Shell 6in. H.E. 413E.	17.11.15	12 ..	G. Cussons, Ltd. ..	12	0	0
	23.12.15	12 ..	Wildt & Co. ..	7	15	0
	13.9.16	1 ..	Wildt & Co. ..	6	7	6
Shell 4·5in. How. 42E.	25.10.15	6 ..	Ackworthie & Co. ..	12	0	0
	13.9.16	1 ..	Wildt & Co. ..	6	7	6
Shell 18-pdr. H.E. 617C.	11.15 5.12.15 23.1.16	50 200 175 ..	Triumph Cycle Co...	1	16	0[1]
	15.12.15	25 ..	Horstmann Cars, Ltd.	1	15	0
	15.10.16	1 ..	Boulton & Paul ..	1	10	0
	15.10.16	1 ..	Hans Renold & Co.	1	10	0
Shell 18-pdr. H.E. 899C.	21.10.15	50 ..	British Thomson-Houston Co. ..	2	10	4
	18.11.15	50 ..	Robert Scaife ..		17	0
	15.1.16	150 ..	Gamble & Co. ..		12	6
Shell 13-pdr. H.E. 689C.	2.11.15	20 ..	British L. M. Ericsson Co.	2	8	11
	22.12.15	1 ..	Tilling-Stevens, Ltd.		10	0
	14.1.16	30 ..	Riley Engine Co. ..		8	9
Rifle Gauges No. 277	16.9.15	6 ..	Stokes & Co. ..		15	0
	15.6.16	10 ..	T. Watson		9	6
Rifle Gauges No. 1051	14.12.15	40 ..	Larkins & Bailey ..	1	5	0
	4.4.16	18 ..	Larkins & Bailey ..		18	0
	20.9.16	27 ..	Larkins & Bailey ..		16	6
Primer Percussion 639C.	25.11.15	25 ..	Wolseley Motors, Ltd.	3	0	0
	30.12.15	6 ..	Pitters Eng. Co. ..	2	10	0
	31.5.16	200 ..	Bassett Lowke, Ltd.	2	2	0
Gaine 393E... ..	9.8.15	50 ..	Imperial Typewriter Co		18	6[2]
	21.9.15	20 ..	Muir & Co. ..	2	12	0
	20.1.16	50 ..	Earth Driven Clock Co.	2	8	0
	14.3.16	70 ..	Earth Driven Clock Co.	2	8	0[3]

[1] R.L. price on October 1, 1915, was £1 14s.
[2] Gauges made at this price not satisfactory.
[3] Order and Supply Lists. Supplements 3 H., 7 H., 11 H.

APPENDIX III.

(CHAPTER I., p. 23.)

Number of Gauges Tested Weekly at the National Physical Laboratory, 1916, 1917 and 1918.[1]

Date.		*Check Gauges.*		*Screw & Profile Gauges.*		*Total of all types dealt with.*	
1916.		*Tested.*	*Passed.*	*Tested.*	*Passed.*	*Tested.*	*Passed.*
January ..	(4)[2]	77	47	605	275	3,332	2,375
February ..	(4)	120	80	842	497	4,435	3,217
March ..	(4)	72	55	1,010	612	3,195	2,262
April ..	(5)	64	40	950	650	2,624	1,988
May ..	(4)	65	42	845	570	3,150	2,365
June ..	(4)	77	55	930	552	4,155	3,177
July ..	(5)	120	84	1,066	654	4,495	3,398
August ..	(4)	105	82	1,500	962	4,965	3,905
Sept. ..	(5)	122	80	1,128	734	4,574	3,564
October ..	(4)	105	77	1,104	930	4,670	3,530
November	(4)	112	70	1,337	880	4,692	3,460
Dec. ..	(5)	238	120	1,310	832	5,532	4,336
1917.							
January ..	(4)[2]	160	105	1,230	785	6,735	5,077
February ..	(4)	180	135	1,870	1,200	8,782	6,255
March ..	(5)	172	118	1,970	1,314	9,444	7,398
April ..	(4)	202	145	1,672	1,122	8,652	6,707
May ..	(4)	152	80	2,337	1,552	10,032	7,560
June ..	(5)	238	144	2,072	1,350	8,612	6,674
July ..	(4)	115	77	3,072	2,227	11,015	8,367
August ..	(4)	150	87	2,067	1,442	9,835	7,285
Sept. ..	(5)	156	94	3,066	2,248	10,400	7,720
October ..	(4)	162	97	2,835	1,955	9,820	7,352
Nov. ..	(4)	145	90	3,050	2,097	9,840	7,017
December	(5)	148	122	2,970	2,286	9,210	6,694

1918.		*Check.*		*Screw.*		*Form & Profile*		*Total of all types dealt with.*	
		Tested	*Passed*	*Tested*	*Passed*	*Tested*	*Passed*	*Tested*	*Passed*
Jan. ..	(4)[2]	111	66	2,414	1,759	572	325	8,000	5,769
Feb. ..	(4)	145	105	2,717	1,840	418	257	7,131	5,012
Mar. ..	(5)	146	83	2,846	1,842	278	167	6,474	4,366
April ..	(4)	98	65	3,238	2,364	209	137	6,473	4,689
May ..	(4)	142	93	2,409	1,792	263	177	5,927	4,280
June ..	(5)	127	94	2,810	2,015	189	155	7,230	5,257
July ..	(4)	77	49	2,265	1,693	135	81	6,260	4,458
Aug. ..	(5)	63	39	2,052	1,632	174	111	5,780	4,389
Sept. ..	(4)	74	46	2,549	1,983	174	127	6,329	4,816
Oct. ..	(4)	117	79	3,006	2,512	160	130	6,621	5,174
Nov. ..	(5)	102	65	2,497	1,940	144	127	5,478	4,098
Dec. ..	(3)	84	60	2,528	1,954	58	33	4,757	3,486

[1] This does not represent the total output of gauges, since all rifle gauges are tested at Enfield Lock, and gun gauges and certain gun ammunition gauges are tested at Woolwich (*see* pp. 32 and 35). The table is prepared from charts supplied by the Gauge Department. The figures are only approximate.

[2] Number of weeks in month.

APPENDIX IV.

List of Technical Reports and Papers dealing with Gauges, etc.

1. "Limit Gauges," by Sir R. T. Glazebrook. (*Engineering*, 8 and 15 September, 1916.)
2. Three articles on Gauge Measuring and Equipment at the National Physical Laboratory. (*Engineering*, 16, 23 and 30 August, 1918.)
3. Leaflet *re* Hoffmann Rollers. (D.A.O./G.8A, issued by Ministry of Munitions, 7 September, 1916.)
4. "Notes on Screw Gauges," by the Gauge Testing Staff of the National Physical Laboratory. (Published by H.M. Stationery Office.)
5. Paper on "Screw Thread Measurement," read before the Liverpool Engineering Society, 10 January, 1917, by Arthur Brooker.
6. Paper on the "Manufacture of Gauges," read before the Institution of Mechanical Engineers at the L.C.C. Paddington Technical Institute.
7. Report on British Standard Fine (B.S.F.) Screw Threads and their tolerances (No. 84) by the British Engineering Standards Association.
8. Gauge Making and Lapping. (Machinery's Ref. Series No. 64.)
9. Hardening and Tempering. (Machinery's Ref. Series No. 46.)
10. Screw Thread Cutting. (Machinery's Ref. Series No. 32.)
11. Screw Thread Tools and Gages. (Machinery's Ref. Series No. 31.)
12. Article in *American Machinist* of 20 December, 1917, on "The Inspection of Screw Gages for Munitions of War," by H. J. Bingham Powell.
13. Verification of Gauges at the National Physical Laboratory. (G.C.4, issued by the Ministry of Munitions, 9 October, 1916.)

APPENDIX V.

(CHAPTER II., p. 41.)

Constitution of Advisory Committees on Machine Tools.

1. CONSTITUTION OF THE MACHINE TOOL ADVISORY COMMITTEE.

(*a*) *July*, 1915.

Mr. Alfred Herbert (Chairman).
Provost W. B. Lang (Vice-Chairman, Scotland).
Mr. J. W. S. Asquith (Yorkshire and District).
Mr. W. F. Clark (London, Birmingham, Bristol, etc.).
Mr. W. D. Ford-Smith (Lancaster and District).
Mr. G. H. Churchill (Importers).
Mr. E. M. Iliffe (Secretary).

(*b*) *November*, 1918.

Provost W. B. Lang (Chairman) Mr. J. W. S. Asquith (Vice-Chairman) Sir Alfred Herbert, K.B.E. Mr. E. M. Griffiths Mr. L. H. Ransome Mr. W. D. Ford-Smith	Representing the Machine Tool Trade.
Sir Richard Cooper, Bart., M.P. (Finance Department) Mr. E. M. Iliffe (Controller, Machine Tool Department) Mr. J. W. Milne (Contracts Department and Prices Section) Mr. J. D. Steven (Small Tools Section) Mr. L. G. Wykes (Secretary)	Ministry of Munitions.

2. CONSTITUTION OF THE SMALL TOOL ADVISORY COMMITTEE SEPTEMBER, 1918.

Mr. E. M. Iliffe (Chairman).

Mr. H. Arnison Mr. A. Balfour Mr. J. H. Barker Mr. S. H. March Mr. P. McGregor Mr. J. Neill Mr. W. S. Skelton Mr. Pye Smith	Representing the Small Tool Trade.

Sir Richard Cooper, Bart., M.P.
Mr. S. R. Judd
Mr. J. W. Milne
Mr. J. D. Steven
} Representing the Ministry of Munitions.

Mr. L. G. Wykes (Secretary).

3. Constitution of the Merchants and Importers' Advisory Panel, September, 1918.

Mr. E. M. Iliffe (Chairman).

Mr. F. M. Burns
Mr. T. S. Catmur
Mr. A. L. Churchill
Mr. A. Denton
Mr. W. Hatch
Mr. A. T. Parry
Mr. J. Pickin
Mr. E. A. Savage
Mr. T. W. Simpson
Mr. J. T. Stuart
Mr. L. H. Turtle
} Representing the Merchants and Importers.

Mr. F. E. Bagnall
Sir Richard Cooper, Bart., M.P.
Mr. J. W. Milne
} Representing the Ministry of Munitions.

Mr. L. G. Wykes (Secretary).

APPENDIX VI.

(CHAPTER II., p. 47.)

War Office Circular to Machine Tool Contractors.

War Office,
London, S.W.,
May, 1915.

GENTLEMEN,

I am commanded by the Army Council to inform you that, in order to expedite work on completion of contracts for the supply of munitions of war, which are urgently needed for our armies in the field, it is necessary that supplies of all machine tools, presses or other similar appliances in the country should be made immediately available for the manufacture of such munitions of war.

I am to instruct you accordingly to divide all the orders relating to the articles above mentioned in progress at your works at or elsewhere, and also all other such orders that you may have on your books, into two classes as shown below :—

A.

Orders for British and Allied Governments ;

Orders for British and Allied Armaments Companies ;

Orders for Contractors and sub-contractors to the above, in cases where the orders are for use on Government contracts or sub-contracts ;

Orders for British Colonies or for India, in cases where you have actual knowledge that the orders are for direct or indirect use in the production of munitions of war.

B.

Orders for neutral countries, whether or not covered by the prohibition order referred to below ;

Orders for British Colonies or for India, in cases where you have no actual knowledge that the orders are for use in production of munitions of war ;

Orders for British firms for machinery which is not to be used directly or indirectly in the production of munitions of war.

As regards delivery under your contracts, you are hereby instructed to give preference to Class A before Class B. Moreover, wherever earlier delivery of orders in Class A can be given by diverting or suspending orders in Class B, you are directed so to divert or suspend, and this without regard to any contracts or obligations you may be under in respect of orders in Class B.

All future orders which would come under Class B are to be accepted only on the understanding that they are liable to suspension, diversion and delay, and that they cannot in any case be executed so long as you have similar orders unexecuted in Class A, even if such orders in Class A are of later date.

Your attention is called to the following extract from the Defence of the Realm (Amendment) Act :—

> " It is hereby declared that where the fulfilment by any person of any contract is interfered with by the necessity on the part of himself or any other person of complying with any requirement, regulation, or restriction of the Admiralty or the Army Council under the Defence of the Realm Consolidation Act, 1914, or this Act, or any regulations made thereunder, that necessity is a good defence to any action or proceedings taken against that person in respect of the non-fulfilment of the contract so far as it is due to that interference."

and to Regulation 8a of the Defence of the Realm Consolidated Regulations as follows :—

> " It shall be lawful for the Admiralty or Army Council (*a*) to require any work in any factory or workshop to be done in accordance with the directions of the Admiralty or Army Council, given with the object of making the factory or workshop or the plant or labour therein as useful as possible for the production of war material ; (*b*) to regulate or restrict the carrying on of work in any factory or workshop or remove the plant therefrom, with a view to increasing the production of war material in other factories or workshops, and the occupier and every officer and servant of the occupier of the factory or workshop, and where the occupier is a company, every director of the company, shall obey the directions, regulations, or restrictions of the Admiralty or Army Council so given, and if he fails to do so he shall be guilty of an offence against these regulations."

and to the following Order in Council under date of 26 April, 1915 :—

> " That the following articles should be added to the list of goods the exportation of which is prohibited to all foreign ports in Europe and on the Mediterranean and Black Seas, other than those of France, Russia (except Baltic ports), Spain and Portugal :—
>
> " Raw cotton.
> " Metal working machinery."

I am to request that you will forward at once an acknowledgment of the receipt of these instructions to Machine Tool Department, Cecil Chambers, 76, Strand, London, W.C.

This letter has been addressed simultaneously to all the firms whose names are in the attached schedule.

I am,
Gentlemen,
Your obedient Servant,
R. H. BRADE.

APPENDIX VII

(CHAPTER II., p. 48.)

Ministry of Munitions Circular to Machine Tool Contractors.

Ministry of Munitions,
6, Whitehall Gardens, S.W.
24 *July*, 1915.

GENTLEMEN,

The Army Council, by an Order dated May, 1915, instructed you to divide all orders for machine tools into two classes, " A " and " B," and instructed you to give precedence to Class " A."

A subsequent Order of the Army Council further instructed you to accept no orders for machine tools, except for British and Allied Governments, their Contractors and Sub-Contractors, without the express permission of the War Office, and further instructed you to make certain returns as to work in progress.

In view of the continued heavy demands for machine tools for the manufacture of munitions of war, it has now become necessary for the Minister of Munitions, in the exercise of the powers conferred on him by the Ministry of Munitions Act, 1915, and by the Ministry of Munitions Order, 1915, and with the assent of the War Office, to assume more complete control over the machine tool trade of the country.

I am therefore to instruct you that, from this date, you are to accept no orders for machine tools from any Government, person, or persons whatsoever, other than the Minister of Munitions (or such Department or Departments of the Ministry of Munitions as the Minister may authorise), the Admiralty, or the Army Council, except with the express consent of the Minister of Munitions (or such Department of the Ministry of Munitions as aforesaid).

I am further to instruct you that you may, at the discretion of the Minister (or of such Department as aforesaid), be required from time to time to suspend or divert any work of any description which you may have in progress, or to cancel any orders which you may already have received.

I am,
Gentlemen,
Your obedient Servant,
H. LLEWELLYN SMITH.

APPENDIX VIII.

(CHAPTER II., p. 50.)

Prohibition of Importation of Machine Tools.

GEORGE R.I.

WHEREAS by Section forty-three of the Customs Consolidation Act, 1876, it is provided that the importation of arms, ammunition, gunpowder or any other goods may be prohibited by Proclamation.

And whereas it is expedient that the importation into the United Kingdom of machine tools and parts thereof, excluding small tools, should be prohibited as hereinafter provided :

Now, Therefore, We, by and with the advice of Our Privy Council, in pursuance of the said Act and of all other powers enabling Us in that behalf, do hereby proclaim, direct and ordain as follows :—

As and after the 21st day of December, 1915, subject as hereinafter provided, all machine tools, and parts thereof, excluding small tools, shall be prohibited to be imported into the United Kingdom.

Provided always, and it is hereby declared, that nothing in this Proclamation shall apply to machine tools and parts thereof, imported under the licence of the Board of Trade and subject to the provisions and conditions of such licence.

This Proclamation may be cited as the Machine Tools (Prohibition of Import) Proclamation, 1915.

Given at Our Court at Buckingham Palace, this thirtieth day of November, in the year of our Lord one thousand nine hundred and fifteen, and in the Sixth Year of Our Reign.

GOD SAVE THE KING.

APPENDIX IX.

(Chapter II., p. 60.)

Control of Sale and Purchase of Machine Tools.

28 *August*, 1916.

In pursuance of the powers conferred upon him by Regulation 30 (A) of the Defence of the Realm (Consolidation) Regulations 1914, the Minister of Munitions hereby orders that the war material to which the Regulation applies shall include war material of the following classes and description, namely :—

All machine tools and machinery driven by power and suitable for use in cutting, stamping or working metal, including :—

Lathes.
Milling machines.
Drilling machines.
Planers.
Shapers.
Screw machines.
Chucking machines.
Boring machines.
Slotting machines.
Grinding machines.
Boring and turning mills.
Power presses.
Punching and shearing machines.
Forging machines.
Cutting-off machines.
Gear-cutting machines.
Centring machines.

Notice of General Permit under the above Order.

28 *August*, 1916.

The Minister of Munitions gives notice (1) that he hereby permits all persons until further notice to purchase or enter into negotiations for the purchase of the war material referred to in the above Order Provided that such purchase or negotiations are from or with persons holding a special permit from the Minister to sell such war material and not otherwise ; (2) that he hereby permits the insurance of any such war material.

All applications for a special permit in connection with the above Order should be addressed to the Director of Machine Tools, Armament Buildings, Whitehall Place, London, S.W.

APPENDIX X.

(CHAPTER II., p. 51.)

Control of Sale and Purchase of Wood-working Machinery.

5 *June*, 1917.

In pursuance of the powers conferred upon him by Regulation 30a of the Defence of the Realm Regulations, the Minister of Munitions hereby orders that the war material to which that Regulation applies shall include war material of the following classes and descriptions, namely :—

All machinery driven by power and suitable for use in cutting, working, or operating on wood, including :—

Sawing machines of all descriptions.
General joiners.
Mortise, tenon and boring machines.
Lathes and rounding machines.
Box and cask-making machines and all machines accessory thereto.
Scraping and sandpapering machines.
Wheelwright machinery.
Firewood-making and bundling machinery.
Wood wool fibre and pulp machinery.
Saw-sharpening and setting machines.
Saw stretchers and brazing apparatus.
All machines for grinding, planing or moulding irons.

NOTICE.

All applications for a permit to purchase or enter into negotiations for the purchase of the war material referred to in the above Order should be made to the Executive Officers of the Area Clearing House Boards, whose addresses may be obtained upon application to " The Director, Central Clearing House, Ministry of Munitions, Charing Cross Buildings, S.W. 2."

All applications for a permit to sell or enter into negotiations for the sale of the war material referred to in the above Order should be made to " The Director of Wood-working Machinery, Charing Cross Buildings, S.W. 2."

APPENDIX XI.

(CHAPTER II., p. 53.)

Control of Manufacture of Small Tools.

10 *May*, 1918.

The Minister of Munitions in exercise of the powers conferred upon him by the Defence of the Realm Regulations and all other powers thereunto enabling him hereby orders as follows :—

1. No person shall on or after the 1st day of June, 1918, until further notice, manufacture any small tool as hereinafter defined, or any part thereof, except under and in accordance with the terms of a licence issued under the authority of the Minister of Munitions.

2. Every person engaged in the manufacture of Small Tools shall make such returns with regard to his business as shall from time to time be required by or under the authority of the Minister of Munitions.

3. For the purposes of this Order the expression " Small Tools " shall mean all or any Engineers' or Machinists' small tools and shall include the following :—

Abrasive Wheels.
Adjustable Clamps.
Auger Bits.
Band Saws.
Boring Heads.
Callipers.
Chasers.
Chucks.
Circular Saws.
Dial Gauges.
Dies and Die Stocks.
Die Heads.
Drills.
Drill Sleeves and Sockets.
Emery Wheel Dressers.
Expanding Mandrels.
Expansion Bits.
Files.
Furniture and Dovetailed Bits.
Gauges.
Hacksaw Blades.
Hand and Breast Drills.
Hand Grinders.
Hide Hammers.
Lathe Carriers.
Lathe Dogs.
Lead Hammers.
Machine Vices.
Measuring Tapes and Rules of all descriptions, including Verniers.
Micrometers.
Milling Cutters.
Pipe Cutters.
Pipe Vices.
Pipe Wrenches.
Pliers.
Punches.
Reamers.
Screwing Tackle (*i.e.*, Chasers, Dies and Stocks, Taps and Thread Milling Cutters).
Swage Shapers.
Tapping Attachments.
Taps.
Tap Wrenches.
Tool Holders.
Tube Expanders.
Wood Boring Bits.

4. All applications for licences under this Order shall be addressed to the Controller of Machine Tools, Charing Cross Buildings, London, W.C. 2, and marked " Small Tools."

5. This Order may be cited as the Small Tools Order 1918.

APPENDIX XII.

(CHAPTER II., p. 58.)

Deliveries and Imports of Machine Tools during 1918.[1]

DATE.	VALUE OF MACHINE TOOLS (including Small Tools).		MACHINE TOOL IMPORTS.	
	Sanctioned Monthly.	*Delivered Monthly.*	*In Tons per Month.*	
		£		
January	1,231,645	1,046,315	3,360	
February	1,083,468	796,268	1,589	
March	877,280	551,912	1,895	
April	1,301,575	842,705	2,701	Out of total imports for 1918, 38,853 tons, 38,478 came from America.
May	905,908	729,200	5,174	
June	959,096	938,476	3 804	
July	1,015,405	1,079,215	4,136	
August	1,051,784	815,868	4,010	
September	1,123,360	831,228	2,515	
October	1,467,595	1,004,670	3,249	
November	—	—	2,573	
December	—	—	3,847	

[1] The only figures available for 1916 and 1917 are those for sanctions, the average monthly value of which is given on p. 58.

APPENDIX XIII.

(CHAPTER II., p. 68.)

Labour in the Machine Tool Trade.

	Men.	*Women.*	*Total.*
January, 1916	41,173	1,096	42,269
January, 1917	33,142	3,259	36,401
June, 1917	32,450	3,904	36,354
January, 1918	22,800	6,200	29,000
July, 1918	20,300	6,600	26,900
September, 1918	20,800	6,700	27,500

APPENDIX XIV.

(CHAPTER III., p. 77.)

Control of Manufacture, Sale and Purchase of Ball Bearings.

1 *November*, 1917.

The Minister of Munitions in exercise of the powers conferred upon him by the Defence of the Realm Regulations and all other powers thereunto enabling him HEREBY ORDERS as follows :—

1. No person shall on or after the date hereof until further notice manufacture any ball bearing or roller bearing (both of which are hereinafter included in the expression "ball bearing"), or any part thereof except under and in accordance with the terms of a licence issued under the authority of the Minister of Munitions.

2. No person shall on and after the date hereof until further notice sell, supply or deliver any ball bearing or any part thereof whether situated in or outside the United Kingdom, or purchase or negotiate for the purchase or take delivery of any ball bearing or any part thereof situated outside the United Kingdom except under and in accordance with the terms of a licence issued under the authority of the Minister of Munitions.

3. All persons engaged in the manufacture or sale of ball bearings shall make such returns with regard to their businesses as shall from time to time be required by or under the authority of the Minister of Munitions.

Note.—All applications in reference to this Order should be addressed to the Director of Ball Bearings, T.M. 3, Ministry of Munitions, Whitehall Place, London, S.W. 1, and marked "Ball Bearings."

APPENDIX XV.

(CHAPTER III., p. 86.)

Progressive Increase in Output of Ball Bearings from Home Factories.

Firm.	Period.			Estimated output on completion of extensions.
	4th quarter, 1916.	4th quarter, 1917.	Sept. to Nov., 1918	
	Average per month.	Average per month.	Average per month.	
Hoffmann Co.	87,490	117,794	160,720	172,000
Skefko Co.	20,000	31,246	25,540	80,000
Ransome and Marles ..	6,262	9,690	18,827	25,000
Electric Ordnance Accessories Co.	5,183	5,541	6,150	8,000 ?
Rudge Whitworth, Ltd. ..	—	—	6,488	80,000
Auto Machinery Co. ..	8,422	9.252	10,280	10,000 (No extension)
Mair, Nixon and Ferguson..	318	693	1,265	2,000 ?
Total	127,675	174,216	229 270	377,000

APPENDIX XVI.

(CHAPTER III., p. 90.)

Total Supplies of Ball Bearings from November, 1917, to October, 1918 (including American).

	Home Supplies.		Overseas Supplies.		Total.
1917.		%		%	
November	189,060	56·9	142,973	43·1	332,033
December	161,693	57·4	120,156	42·6	281,849
1918.					
January	188,468	39·7	286,051	60·3	474,519
February	179,678	50·2	178,236	49·8	357,914
March	180,835	37·9	296,867	62·1	477,702
April	175,228	62·4	105,654	37·6	280,882
May	188,105	40·8	273,259	59·2	461,364
June	184,734	50·3	182,438	49·7	367,172
July	201,993	57·9	146,988	42·1	348,981
August	120,357	49·4	123,378	50·6	243,735
September	203,598	56·4	157,343	43·6	360,941
October	313,576	64·6	171,918	35·4	485,494
Monthly average	190,610	51·2	182,105	48·8	372,715

APPENDIX XVII.

(CHAPTER IV., p. 105.)

Principal Electric Power Supply Undertakings Increasing their Capacity between 1914 and 1918.

I.—MUNICIPAL UNDERTAKINGS.

(*a*) Stations above 5,000 kilowatt capacity in 1914 which doubled their capacity (approximately).

Corporation.	*Plant Capacity at 30 June, 1914.*	*Additional Plant installed or authorised between 30 June, 1914, and 31 October, 1918.*
	Kilowatts.	*Kilowatts.*
Aberdeen	8,380 ..	9,380
Battersea	5,092 ..	5,000
Birmingham	33,000 ..	51,650
Bolton	7,600 ..	10,900
Bradford	16,800 ..	27,450
Coventry	12,000 ..	13,200
Derby	7,050 ..	7,500
Glasgow	54,900 ..	99,050
Greenock	11,900 ..	21,100
Leeds	22,940 ..	33,660
Oldham	5,340 ..	7,050
Rochdale	5,476 ..	5,780
Rotherham	5,150 ..	65,350
Salford	8,500 ..	9,500
Sheffield	23,225 ..	73,000
Stepney	7,720 ..	9,480
Swansea	5,100 ..	5,000
Wolverhampton	7,050 ..	16,450

(*b*) Stations above 5,000 kilowatt capacity which extended but did not double their capacity.

Corporation.	*Plant Capacity at 30 June, 1914.*	*Additional Plant installed or authorised between 30 June, 1914, and 31 October, 1918.*
Belfast	13,300	10,500
Brighton	12,100	4,000
Bristol	15,050	9,000
Bury	5,700	3,000
Cardiff	8,200	3,000
Edinburgh	17,980	2,500
Halifax	7,500	5,500
Hampstead	5,889	1,500
Huddersfield	7,450	4,000
Hull	10,210	5,000
Leicester	7,450	6,000
Liverpool	*37,000	*10,000
L.C.C. Tramways	38,500	9,000
Manchester	72,300	46,450
Newport	7,100	3,000
Plymouth	5,475	4,800
Poplar	10,000	4,250
St. Pancras	8,850	3,000
Shoreditch	5,680	5,000
Southampton	5,500	3,000
Sunderland	8,500	7,500
Stalybridge	18,000	1,000

* Mersey Power Company extended from 4,900 to 24,500.

II.—Company Undertakings.

Stations above 5,000 kilowatt capacity in 1914 which extended their capacity.

Company.		
Central Electric	26,283	7,570
Charing Cross	23,480	3,000
City of London	27,000	6,000
Clyde Valley	35,000	37,500
Cornwall	6,745	3,000
County of London	19,800	14,400
Kensington and Knightsbridge	9,390	500
Lancashire Electric	16,500	6,000
London Electric Supply	25,450	12,000
Metropolitan	22,500	4,000
Midland Electric	10,600	10,200
Newcastle-upon-Tyne and Associated Companies.	86,200	114,200
Newcastle and District	9,000	8,000
North Metropolitan	16,122	21,068
Shropshire, Worcester and Staffs	28,325	15,850
South Metropolitan	6,000	15,000
South Wales	10,500	5,000
Trafford	5,200	7,950
Yorkshire Electric	14,300	12,200

APPENDIX XVIII.

(CHAPTER IV., p. 102.)

Control of Purchase, Manufacture and Installation of Electric Converter Plant.

5 *April*, 1918.

The Minister of Munitions in exercise of the powers conferred upon him by the Defence of the Realm Regulations and all other powers thereunto enabling him hereby orders as follows :—

1. No person shall on or after the date hereof until further notice purchase or manufacture, or erect or instal in or in connection with any factory, workshop, steel works, shipyard, colliery or other premises for the purposes of which alternating current is or can be made available, any rotary converter plant, motor generator plant or converter plant of any description for transforming alternating current to direct current, or any part of such plant (all or any of which shall be included in the expression " converter plant ") except under and in accordance with the terms of a licence issued on behalf of the Minister of Munitions by the Director of Electric Power Supply.

2. Nothing herein contained shall prevent the carrying out of any necessary repair to converter plant already installed at the date hereof, or the purchase, manufacture, erection or installation of converter plant required solely for electro-chemical or electrolytic processes or electric traction.

3. All applications in connection with this Order shall be made to the Director of Electric Power Supply, Ministry of Munitions, 8, Northumberland Avenue, W.C. 2.

4. This Order may be cited as the Converter Plant Control Order, 1918.

Note.—The licence required by this Order is in addition to and not in lieu of the usual Priority Certificates and permit reference number.

Applicants for licences are warned against purchasing or installing direct current motors before the licence for the necessary converter plant has been obtained.

APPENDIX XIX.

(Chapter IV., p. 103.)

Control of Electricity Supply.

8 *November*, 1918.

The Minister of Munitions in exercise of the powers conferred upon him by Regulation 11a of the Defence of the Realm Regulations and all other powers thereunto enabling him hereby orders as follows :—

1. No person shall on or after the date hereof except under and in accordance with the terms of a permit issued under the authority of the Minister of Munitions :—

(*a*) Connect or cause to be connected to any source or means of supply of electricity any place or any building, premises or plant or any part thereof not so connected at the date hereof, or

(*b*) Supply or cause to be supplied any electricity to any place or any building, premises or plant or any part thereof not supplied with electricity at the date hereof, or

(*c*) Use or cause to be used any electricity in or at any such place, building or premises or for the purpose of any such plant as hereinbefore mentioned.

Provided that in any case coming within the scope of the Household Fuel and Lighting Order, 1918, or the Household Fuel and Lighting (Scotland) Order, 1918, as defined by Clause 1 of these Orders respectively, where the previous assent of the Local Fuel Overseer is required and has been duly obtained to any fitting, equipment or supply under Clause 99 of the first mentioned Order or Clause 77 of the secondly mentioned Order, no permit hereunder shall be required for such fitting, equipment or supply or the use of such supply.

2. All applications with reference to this Order should be addressed to the Director of Electric Power Supply, Ministry of Munitions, 8, Northumberland Avenue, London, W.C. 2.

3. This Order may be cited as The Electricity (Restriction of New Supply) Order, 1918.

Note.—The permission required by the Order is in addition to and not in lieu of the usual Priority Certificates and permit reference number.

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Printed by H.M. Stationery Office Press, Dugdale Street, S.E.

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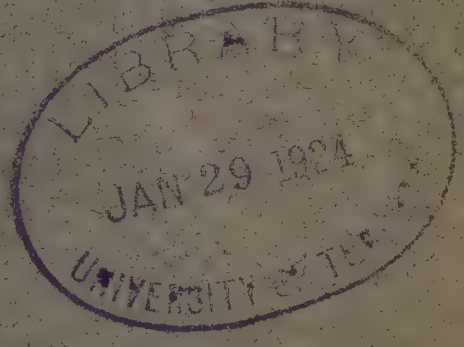
HISTORY OF THE MINISTRY OF MUNITIONS

VOLUME VIII

THE CONTROL OF INDUSTRIAL CAPACITY AND EQUIPMENT

PART IV

CONTROL OF ENGINEERING CAPACITY: ADMINISTRATIVE MACHINERY



1921

Volume VIII

THE CONTROL OF INDUSTRIAL CAPACITY AND EQUIPMENT

PART IV

CONTROL OF ENGINEERING CAPACITY: ADMINISTRATIVE MACHINERY

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PART IV.

CONTROL OF ENGINEERING CAPACITY: ADMINISTRATIVE MACHINERY.[1]

I. Introduction.

Among the many vital problems facing the Ministry at its inception were the relative claims of local autonomy and centralised control from headquarters. It was obvious from the beginning that such a vast organisation as was contemplated by Mr. Lloyd George would necessitate a certain measure of administrative devolution. The proper utilisation of hitherto untouched industrial resources, the assistance and encouragement of new firms, the introduction of improved methods of manufacture, and the adaptation and installation of new equipment and machinery, all required close supervision, together with a generous freedom of adaptability to varying local circumstances. Yet local autonomy brought with it the dangers of misdirected effort, overlapping administration, conflict of aim, lack of uniform procedure, and financial extravagance. The choice thus lay between the Scylla of over-great centralisation and the Charybdis of too much local independence; success in producing the much-needed munitions depended upon the skill of the helmsman in keeping a middle course between the two.

II. Area Office Organisation with Superintending Engineers.[2]

A solution was sought in the creation of the administrative machinery known as Area Organisation. It was at first contemplated that in addition to the headquarters organisation established at Whitehall, branch offices of the Ministry would be established in each of the ten areas into which the United Kingdom was to be divided. The original intention was that each Area Office should form an administrative unit with an officer at its head entrusted with the responsibility of taking action within the limits of general policy determined at headquarters. Each Area Office would have a Secretary, a Superintending Engineer, and a Labour Officer. In the original scheme for the organisation of the Area Offices the Secretary was indicated as the responsible officer, but later the Superintending Engineer became the head, and the Secretary acted as his subordinate. The Superintending Engineer was to deal with all matters arising from every branch of munitions production within the area,[3] while a Labour

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[1] Hist. Rec./H/1126/1; Hist. Rec./H/1600/10; Hist. Rec./H/263.71/3; Hist. Rec./H/1500/6; Hist. Rec./R/1710/1, 2, 5, 6; Hist. Rec./H/1200/6.

[2] A full account of the work of the Area Office under the Department of Area Organisation will be found in Vol. II, Part II.

[3] Except trench warfare supplies, which had local officers from the very beginning outside and independent of Area Organisation. (*See below, p.* 3.)

Officer was to control similarly the supply of labour within the area.[1] These three officers and their staff were to be the link between local firms and headquarters, advising the latter in the placing of orders by means of their local knowledge, and placing the collective experience of all areas at the disposal of the former in order to obtain the greatest possible production. In so far as the Area Offices were to be permitted a good deal of independence in assisting firms in the actual performance of contracts, it was expected that this organisation would conduce to speed and economy in output ; while the fact that policy would be dictated from headquarters and all orders for the supply of different classes of munitions within the area would go through a single channel would produce balance of supply and co-ordination of effort.

The principle behind this scheme is clear and simple. Unfortunately its applicability in practice was limited by the circumstances of the time and the interests and energies of the men who were to work the scheme. For these reasons the scheme was difficult to carry out with logical balance and completeness. In 1915 the output of empty shell was the most urgent preoccupation of the Ministry, and consequently from the first the energies of the Area Offices were concentrated on the task of speeding up the output of shell. The Superintending Engineer, instead of being an impartial local representative of all headquarters departments, became largely identified with the Department of Shell Manufacture. In consequence, other departments began to appoint their own staff for local purposes who were responsible only to their own departmental head at headquarters, though if their work lay in a definite area they generally used the Area Office as their local centre. In consequence of this virtual supersession of the centralised directing authority of the Superintending Engineer within the area, the evils of conflicting jurisdiction, multiplication of officials, and absence of co-ordination began to appear.

To understand the position of the Superintending Engineer, it must be borne in mind that his functions theoretically continued to be comprehensive and he still remained the principal representative of the Ministry of Munitions in the area. Broadly speaking, his task was to obtain full knowledge of all the engineering possibilities of the district and develop its resources for munitions manufacture as fully as possible on lines laid down from time to time by the Ministry. His advice and assistance were freely at the disposal of individual contractors. He was the chief authority in the district on the use of machinery, and in many cases exercised a concurrent authority with the Labour Officer with regard to the use of skilled labour. He had to advise the Ministry as to the capacity of firms to carry out proposed contracts and as to the possibilities of sub-contracting and of establishing new types of engineering industry in the area. In addition, he had to keep a watchful eye on the general progress of manufacture, assisting firms to instal labour and power-saving devices and aiding them to overcome obstacles which threatened to hinder

[1] Hist. Rec./H/1121/6 ; Hist. Rec./H/1121/2.

production. It is easy to see that, with such a broad charter, the possibilities of conflict with the representatives of individual departments were many, and as the tendency for departments to set up their own outside staff increased, the position of the Superintending Engineer became more and more invidious. If he carried out his duties to the full extent laid down, he found his work continually overlapping, if not actually in conflict with the work of other officials; if, on the other hand, he limited his functions to the shell shops he lost the comprehensive outlook and command necessary for co-ordination of effort throughout the industry.

The position had an equally bad influence on the manufacturing firms in the area. They found different departments competing for their capacity, and the temptation to play off one against another was almost irresistible. Moreover, they were harassed by the visits of numerous officials whose instructions and requirements were often irreconcilable and who frequently appeared to duplicate each other's enquiries. Though time and experience brought some amelioration and adjustment, the growing pressure of war necessity prevented the establishment of any satisfactory equilibrium. From the chronic impasse thus created a radical reorganisation offered the only means of escape. It was the realisation of this necessity that led to the proposal to establish a Department of Engineering in the latter part of 1917.

Some slight measure of co-ordination between these multifarious local inspection and progress authorities was brought about by the fact that when practicable the local officials of all the Ministry of Munitions supply departments were housed in the Area Offices. This was an obvious advantage from the point of view of the manufacturer, who grew to regard the Area Office as the centre of information on every point, and it made communication and co-operation between the different local staffs easier. But in so far as these different officials were under no real local control, the Area Office became an agglomeration of units instead of an organisation with interdependent parts, and thus the original idea of the Area Office disappeared under the pressure exercised by individual supply departments at headquarters.

Before turning to the history of this development it is necessary to consider briefly the other branches of the Ministry exercising local control which were in existence before the end of 1917, since the Department of Engineering was created by the absorption of these and the Area Offices into one comprehensive organisation.

III. Some other Forms of District Organisation.

(*a*) Outside Engineering Branch of the Trench Warfare Supply Department.

The most important as well as the oldest of the departmental local organisations was the Outside Engineering Branch of the Trench Warfare Supply Department. The nucleus of this branch was in

existence before the Ministry was established, being a part of the War Office organisation concerned with the supply of trench warfare materials. When this became a function of the Ministry of Munitions, the existing department was taken over as a whole, and therefore the Outside Engineering Branch automatically became part of the organisation of the Ministry and from the first stood outside the scheme of local administration embodied in the Area Organisation machinery. The Outside Engineering Branch was entirely controlled by the Trench Warfare Supply Department in London, and until October, 1915, its staff worked in the provinces without any recognition whatever of the existence of the Area Office. It was the regular channel for communication between the Trench Warfare Supply Department and its contractors. Its functions were to inspect and select suitable works for the manufacture of trench warfare supplies, to assist manufacturers in every possible way with advice and encouragement, to help in obtaining materials and machinery, and to push on manufacture as rapidly as possible.

The lack of co-ordination between the Trench Warfare Supply Department and the Department of Area Organisation resulted not merely in competition and conflicting instructions to manufacturers, but also in the failure of trench warfare officers to obtain complete information regarding the progress of trench warfare contracts placed with Boards of Management. In the autumn of 1915 efforts were made to co-ordinate the activities of the two departments. From this time onwards senior members of the Outside Engineering Branch, under the name of Trench Warfare District Engineers, were located in nine areas,[1] and were assisted by junior engineers known as Trench Warfare Supervisors. They were instructed to co-operate with the Area Engineers to prevent overlapping in the placing of contracts. While the District Engineers were to continue to recommend suitable firms for contracts to the Trench Warfare Supply Department, the actual placing of orders was to take place through the Department of Area Organisation, which was to be kept fully advised of all impending trench warfare requirements. Once the contract was placed, supervision of progress was to remain in the hands of the Trench Warfare District Engineers.

This arrangement failed to secure its end for two reasons. It conflicted with the established policy of the Trench Warfare Supply Department, which had always been based on the principle that, inasmuch as the manufacture of trench warfare material was in a constant state of change, direct control over contractors was absolutely necessary for proper supervision. Moreover, large exceptions were made in the application of the rule as to placing orders through the Area Organisation Department. It was recognised that firms with whom the department had already placed contracts when the arrangement was made must continue to be dealt with directly. In practice

[1] These areas were Newcastle, Manchester, Leeds, Birmingham, Newport, London, Edinburgh, Glasgow, and Ireland.

this exception covered so many contractors that it almost nullified the agreement. In every area it was found that the Trench Warfare Supply Department could continue to place the majority of its contracts without any reference to the Department of Area Organisation.

Further negotiations were set on foot to remedy the situation. It was first proposed that the Trench Warfare Supply Department should be placed under the direct control of the Director-General of Munitions Supply on an equal footing with the other supply departments, when its local engineers could be absorbed into the staff of the Area Offices. But the peculiar problems of trench warfare supply afforded a strong argument against such a procedure, and eventually it was decided to retain the Trench Warfare Supply Department as a separate entity, and to modify the agreement already come to. The Trench Warfare Supply Department was still to have the right to deal directly with existing contractors, but all fresh or repeat orders with such firms were to be placed through Boards of Management. In placing such contracts a statement of requirements and all pertinent particulars were to be sent to the Area Organisation Department, which would then obtain from the Boards of Management a list of firms suitable for undertaking the work. The selection would be made by the Trench Warfare Supply Department on the advice of the Trench Warfare District Engineers ; the order would be placed through the Board of Management, and a notification would be sent to the Department of Area Organisation. The actual administration of the contract would be carried out by the Trench Warfare Supply Department, whose outside engineering staff would still visit and assist progress, acting in harmony with the Area Organisation officials. This arrangement was found more satisfactory, and after some experiment and modification, the system was put into regular working. It was found that about 80 per cent. of the contracts were placed through Boards of Management, the remainder being experimental or peculiarly difficult contracts which it was essential should be placed directly by the Trench Warfare Supply Department.

(*b*) Inspection and Progress Section, Mechanical Warfare Department.

Another example of an independent body of inspecting engineers is to be found in the organisation set up by the Mechanical Warfare Department, which was concerned with the production of tanks. This is of interest because in this case the Ministry entrusted the responsibility for inspection and supervision of progress to the same body of men. In most departments responsibility for acceptance and responsibility for stimulating output were in different hands: the outside engineers or progress inspectors (by whichever name they were called) had no power of passing the finished article: this was done by the staff of the Chief Inspector at Woolwich. The most noteworthy exception, when the Mechanical Warfare Department adopted this system, was the Mechanical Transport Department,

which had been transferred from the War Office in September, 1916, and continued to rely upon its inspecting officers to hasten progress, in accordance with arrangements of some length of standing. From January, 1917, until the autumn of 1918, in the Mechanical Warfare Department the same staff undertook both duties. The Inspection and Progress Section was divided into two parts. The headquarters staff included the Chief Progress Officer who received the reports of the Divisional Inspectors; the Chief Metallurgist, under whose care was the laboratory for testing metals and the heat treatment of steel for armour plate; and other specialists to whom reference could be made by manufacturers or by the Divisional Inspectors. In November, 1918, there were outside Production Officers for engines and spares, components, and armour plate supply. In addition the headquarters staff dealt with all problems of standardisation, interchangeability, shortages, and other matters requiring uniform treatment throughout the country. Local organisation was on the district basis. Certain large towns were chosen as the centres of areas, at the head of which were Divisional Inspectors. In all there were seven areas—London, Lincoln, Birmingham, Manchester, Sheffield, Leeds, and Glasgow. Each area was a self-governing colony. There was no overlapping between the areas and no interference with the authority of the Divisional Inspector from headquarters. Unity in the work of the department was attained by the general direction of district activity by the Chief Progress Officer and by periodical conferences between the Divisional Inspectors and the headquarters staff.

Like the Outside Engineering Branch of the Trench Warfare Supply Department, the Inspection and Progress Section of the Mechanical Warfare Department was entirely independent of the Area Office staff and thus another overlapping local organisation was created.[1] The Divisional Inspectors endeavoured, however, to keep in touch with the area machinery as far as possible, attending the meetings of the Area Organisation Boards and working in harmony with the Superintending Engineers.

(*c*) Ordnance Engineers.

A further example of the development of the specialised local representative to watch progress after the formation of the Area Organisation is to be found in the institution of Ordnance Engineers. These were attached to the Department of Gun Manufacture, and were appointed about the end of 1917. Thus they were a comparatively late development, and seem to have been the direct result of the experience gained in other departments. Over two years of close supervision of shell manufacture by means of the Superintending Engineer and his staff had brought the industry to a high state of

[1] A comparison will show that the area divisions did not coincide. In this the Mechanical Warfare Department differed from the Trench Warfare Supply Department which utilised the existing area divisions for the location of their District Engineers.

efficiency, and had also brought about very considerable economy in manufacture. It was argued, therefore, that a similar organisation would benefit gun manufacture, and from a departmental point of view the argument was sound. But from the point of view of the whole activity of the Ministry, the appointment of Area Ordnance Engineers added another set of officials to increase the congestion already manifesting itself. The Ordnance Engineers were stationed at Manchester, Newcastle, Barrow, Glasgow, Coventry, Erith, and Southampton, and supervised the progress of gun manufacture around these centres. These areas did not coincide with the areas under the Area Organisation scheme any more than did those of the Mechanical Warfare Department, and this created considerable difficulty when later the amalgamation of the engineering staffs under the Department of Engineering was proposed.

(*d*) Gas Engineers.

In order to facilitate the recovery of benzol and toluol in gas works a system of district inspection was established early in 1915. The country was divided into seven areas, each with a representative gas engineer. The areas were then sub-divided into districts which were placed in charge of supervising engineers, whose work was to assist the gas companies to obtain the largest possible amount of toluene from the gas.[1]

IV. Travelling Progress Officers.

Turning to the second form of local control, that exercised from headquarters by means of travelling officers, who were experts in their particular branch of work, the earliest and most complete example is to be found in the Explosives Supply Department.

(*a*) Inspectors of the Explosives Supply Department.

The development of local inspection in this branch of supply was largely empirical at the start, owing to the way in which the Department of Explosives Supply developed out of Lord Moulton's Committee on High Explosives and became first a department of the War Office and then a department of the Ministry of Munitions. The necessity for organisation for local inspection arose from the dangerous and technical character of the manufacture. When the High Explosives Section was formally established in the department of the Master General of Ordnance in January, 1915, a staff of expert travelling inspectors was appointed under the control of the Chief Chemist, Dr. R. C. Farmer. The business of these chemists was to encourage standardisation of process, to inspect materials during the process of manufacture, to arrange for an adequate supply of war materials,

[1] *See* Vol. VII, Part IV, Chap. II.

and to assist firms undertaking the manufacture for the first time. By March, 1915, this organisation of travelling chemists reporting directly to headquarters was in full working order, and when the Explosives Supply Department came under the control of the Ministry of Munitions the organisation was retained. The Explosives Inspectors were in no way connected with the Area Organisation, but were throughout attached entirely to headquarters.

(*b*) Machine Tool Inspectors.

Another example of the system of travelling inspectors is the organisation set up by the Machine Tool Department. These inspectors were all attached to headquarters, and were sent to different parts of the country as necessity dictated. To the usual duties of assisting manufacturers to increase output and of advising the departments as to available capacity was added in their case the duty of seeing that machine tool firms complied with the rules laid down by the department under the different orders controlling the trade. Thus their work went beyond the mere attainment of efficiency in production; they were the channel by which the department controlled the trade and regulated the flow of machinery to meet the urgency of demand from the great munition industries.

(*c*) Travelling Inspectors of other Departments.

The organisations set on foot by the Explosives Supply Department and the Machine Tool Department are typical of the scheme for local inspection gradually developed by all important departments. Wherever the introduction of new firms into an industry was made necessary by the unprecedented demand or wherever the output of old firms needed to be improved, it became necessary for a supply department at the Ministry to introduce a form of progress inspection. In controlled trades this organisation also provided a means of preventing the evasion of the regulations. As time went on, not only output, but also economy of production and utilisation of every available reserve of labour and material became an essential part of the great munitions effort throughout the country, and the system of inspection already established served this end also. It would be tedious to enter into detail with regard to every industry, since the ends, and the means adopted to further the ends, were broadly speaking the same.

Since these travelling officials visited firms that were probably already under the general supervision of the Area Engineer and were possibly being visited for specific contracts by other local officials the burden laid upon the manufacturer grew heavier as each department organised its own outside staff, and practical experience brought home to headquarters the necessity for making some effort to end independent departmental organisation and to create a common service department which should serve all supply departments, and yet be under some central controlling authority.

V. The Central Clearing House.

(*a*) Establishment of the Clearing House, October, 1916.

A tentative attempt to attain this end in the utilisation of manufacturing capacity is to be seen in the establishment of the Central Clearing House. The supervision of the use of machinery was one of the functions of the Superintending Engineer, but his work was limited to the proper use of the machinery in his area : he had little information as to what use was being made of machinery in other areas, and no power to move machinery from one area to another. The result was that frequently there might be many contractors with idle machinery in one area, while from others demands were pouring in to the Ministry for new machinery to fulfil new contracts. The desirability of creating some form of co-ordinating agency was apparent. By placing contracts where spare capacity existed or by transferring idle machines in one area to meet demands in another the pressure on the machine tool makers might be lessened, and at the same time economy of labour and material would be secured. Such a system could only be successful if the controlling agency had detailed knowledge of the spare capacity in the country as well as of the prospective requirements of the principal Government Departments for new capacity. Knowledge of spare capacity could only be obtained through the Area Organisation, and knowledge of prospective requirements necessitated a close touch with headquarters. If an organisation could be created which would bring together the information regarding machinery obtained by the area staffs and place it at the disposal of the supply departments a valuable co-ordinating link would be obtained, and the disastrous effect of local separatism would be overcome.

A proposal for the institution of an Advisory Bureau was the subject of a memorandum by the Director-General of Munitions Supply (Sir Frederick Black) in July, 1916. In his opinion the bureau should have two functions. It ought to advise purchasing departments as to the existence of spare capacity to meet their requirements, and to arrange, through the Machine Tool Department of the Ministry, for the transfer of machine tools from places where they were lying idle. It should be presided over by a man with commercial experience, who would be assisted by a committee representing the Admiralty and the War Office Contracts departments, the Air Service, and the Ministry of Munitions. This committee would be in no sense an executive body, it would have advisory functions only, suggesting directions in which contracts might be placed, but not interfering in any way with the freedom of action of the supply department.

This proposal does not appear to have been acted upon in its entirety : for the actual organisation which was created in October, 1916, differed from it in important particulars. The organisation was to be known as the Central Clearing House. The Director and Deputy Director were to be assisted by an Advisory Board of Heads of Departments at the Ministry, and the Admiralty and the War Office were

to be asked to co-operate. The Central Clearing House was to collect information as to the distribution and use of all existing machinery, and to register idle or partly idle machinery. Demands for new machinery were to be referred by the Machine Tool Department to the Central Clearing House, which would determine how far such demands could be met by existing plant. The Clearing House would also collect information of second-hand machinery not employed on war work. Under this scheme the Clearing House was empowered to deal simply with machinery, not with engineering capacity as a whole. The original idea seems to have been that whatever organisation was created should exercise considerable powers of direction before the placing of contracts: the new procedure resulted in the practice of supply departments choosing firms to carry out contracts, and then applying to the Machine Tool Department for machinery, while the Machine Tool Department in its turn applied to the Central Clearing House to know if any machines could be moved to meet the need.

The idea of a central body to give guidance to supply departments in the placing of contracts appears again, however, in the discussions on the establishment of the Department of Engineering in 1918. Thus the Central Clearing House falls into position as a link between the unco-ordinated individualism of the earlier period of the Ministry's activities and the effort to attain co-ordination and direction which characterises its general policy in 1918. If it be borne in mind that the Central Clearing House as it was actually established was only part, and the less important part really, of a much larger scheme it would appear that the struggle which took place between opposing policies in 1918 was really preceded by a similar though milder one in 1916. At this earlier date the party which stood for the unchecked right of the supply departments to place contracts wherever they would won the day. Nevertheless, the logic of events re-opened the question in a more acute form about a year later, and the Department of Engineering rather than the Central Clearing House represents the idea originated by Sir Frederick Black.

(*b*) Organisation and Work of the Clearing House.

Besides the Central Clearing House at headquarters, Area Clearing Houses were established. An Area Clearing House was located in each of the Area Offices, and an Area Executive Board was set up consisting of the Superintending Engineer, the District Engineer of the Trench Warfare Supply Department, and the Secretary to the Area Office. In addition an area liaison officer was appointed by the Central Clearing House from among the engineers of the Trench Warfare Department, and he, together with the Secretary of the Area Office, did the actual work involved in the tracing and registering of machinery for which the Area Executive Board was responsible.

The successful working of the scheme depended largely on the degree of co-operation which could be attained between the supply departments, the Machine Tool Department, and the Central Clearing

House, at headquarters. At the outset the Director of the Central Clearing House laid down several points of policy which it was essential to carry out. The supply departments must agree to avoid placing contracts with firms who would require new machinery to carry them out and must get an assurance from the contractor that neither he nor his sub-contractors would require new machinery. Failing this assurance, the Clearing House must be applied to in order to ascertain if other facilities were available. Secondly, the Machine Tool Department must supply the Central Clearing House with particulars of new machinery on order or demand, refer to the Clearing House before releasing machine tools, and link up its existing machinery for registering second-hand tools with that of the Clearing House. Finally, the Clearing House must have regular forecasts of the approximate requirements of supply departments and a return of contracts about to be placed or to be extended. In addition to this procedure at the centre, the Area Clearing Houses must trace and register all machines in each area either by means of information supplied by engineering firms themselves or by using the visiting engineers and inspectors of all Government Departments. Co-operation in this respect was important if registration was to be rapid, detailed, and correct. In order to avoid congestion it was laid down that as much decentralisation as possible was to be established. The Area Board might negotiate immediately and on its own responsibility the transference of machines within its area, in the same way as the Superintending Engineer had formerly done. For removal of machinery from one area to another it was necessary to work by way of the Central Clearing House, but careful and detailed procedure was laid down to avoid delay at headquarters.

(*c*) Absorption into the Department of Engineering, February, 1918.

In spite of the careful organisation thus established, the Clearing House system was only a partial success. That it did succeed in utilising a great deal of idle machinery is undoubted: that it did not succeed in bringing requirements and spare capacity into any real relation to one another is equally clear. From the first the supply departments did not co-operate as they should have done, the majority of them continued to place contracts whether or not the contractor had the machinery, and this necessitated either new machinery or an enormous amount of unnecessary transference. The inevitable result of this was congestion, and by 1918 the complaints of delays occasioned by the Clearing House system were frequent. Information was not given to the Clearing House as it should have been, and thus the orderly system which was originally planned degenerated into a mere scramble to meet immediate demands. The system broke down equally in the areas. The Central Clearing House complained of the lack of local control and co-ordination of the activities of the numerous local staffs of the different departments of the Ministry which resulted in the failure to obtain the co-operation which had been stated to be

essential at the beginning of the scheme. As time went on, it became increasingly apparent that the Clearing House organisation would have to be either reformed or abolished. In February, 1918, it was decided that the Central Clearing House should be absorbed in the projected Department of Engineering, and that the Area Clearing Houses should be reorganised as part of the local activity of the new department. As a separate organisation, therefore, the Clearing House ceased to exist.

VI. The Department of Engineering.

The first suggestion for the formation of the Department of Engineering appears at the end of 1917 in the form of a memorandum from the Labour Supply Department, drawing attention to the fact that dilution was handicapped by the shortage of skilled men, and that the skilled men available were being wastefully employed by the irresponsible and unscientific distribution of contracts resulting from the uncontrolled and unco-ordinated efforts of the various supply departments. By that time all the evils inherent in the system of independent departmental activity in the areas had come to a head, and official interference with industry in the country had become a chaos which was apparent, not only to the Ministry and the manufacturers concerned, but also to the commercial world generally. This is shown clearly in a memorandum addressed to the Minister of Munitions by the Association of Chambers of Commerce in November, 1917, in which they pointed out that the diversity of control which permitted competitive purchasing "did not make for economical and efficient material production." In view of the great military effort which the Germans were known to be preparing for the spring of 1918, and of the fact that more then three years of warfare had considerably depleted the country's reserves of material and labour, this efficient national production had become the supreme necessity, and even before the memorandum of the Chambers of Commerce reached the Ministry, it was felt that some steps must be taken to improve the existing state of affairs.

(*a*) Allocation of Contracts Committee, October, 1917.

In October, 1917, the Minister of Munitions (Mr. Churchill) appointed a committee "to consider the best means of allocating contracts for supplies so as to ensure that the contracts are placed with those firms who are best able, with their existing sources of labour and machinery, to provide the output required."

In the discussions of the committee two very sharply contrasted points of view soon became apparent.[1] While all members agreed that an Engineering Efficiency Department was desirable they disagreed on the extent of the power which such a department should exercise, *i.e.*, whether it should be advisory in character or have large executive

[1] Memorandum to Minister by Sir Graham Greene, 1.12.17.

powers. On the one hand it was argued that supervision of production necessarily implied responsibility for output, and that the new department must, therefore, take over the existing functions of the supply departments and the technical officers responsible for directing output. This bold proposal was championed by Sir Glynn West. Other members of the committee considered that production and output could be clearly separated both in theory and in practice. Into the province of the former fell the scientific selection of firms, the efficient use of machinery, and the judicious employment of skilled and semi-skilled labour, while the latter could be secured by the energy, capacity, and business qualities of the administrative departments. Production considered the effective capacity of contractors as a whole to meet the varying needs of supply ; supply was concerned with the output obtained on individual contracts under the conditions laid down by the Department of Production. Supply was, therefore, rather complementary to production, not included in it, and there was no reason why the two functions could not be exercised by different organisations. The group of members holding this view argued for the retention by the supply department of certain of their technical staff with responsibility for output, while establishing a Production Department which should take over those engineers with general rather than specialised functions, such as the staff of the Clearing House and the Area Organisation. Such a department would be supervisory rather than executive in character. It would collect information and arrange the placing of contracts according to the resources available and through its local organisation it would give contractors general assistance in promoting efficiency of manufacture without being responsible for actual output on definite contracts.

Another point of difference was whether the effective power of the new department should be concentrated at headquarters or decentralised among whatever local organisation it might be decided to set up. Those members of the committee who wanted responsibility for output as well as production argued also for centralised control : their scheme was the establishment of a strong department at headquarters with wide executive powers which would use local organisation merely as a channel for carrying out its policy. Other members of the committee opposed this scheme partly from the fear that such a department would tend to become a huge supply department, and partly because they thought that too great centralisation would defeat the whole object of the scheme, and that efficiency could best be secured by allowing considerable autonomy to the local organisation with its detailed knowledge of local conditions and its possibilities of immediate action. According to this view the headquarters organisation would be a body for co-ordinating the work of the officers in the country on the lines of the existing Area Organisation Department. A further reason for advocating this scheme was that by it the co-operation of the War Office, the Admiralty, and other Government Departments would be more likely to be secured, and since the support of all Government Departments was essential to the ultimate success of the scheme this was a consideration of no small importance.

(*b*) Report of the Committee.

It was found extremely difficult to reach any common ground. Eventually, however, a *modus vivendi* was obtained by the suggestion that a beginning might be made with an Efficiency Production Department which would be a step in a natural development without carrying out the larger scheme to the full extent immediately. A compromise was reached whereby, though considerable powers of action would be vested in local officials, decisions involving a veto on the proposals of supply departments would be reserved to headquarters. The measure of agreement thus obtained became the basis of a draft report in which the majority concurred. The report recommended the establishment in the Ministry of an Engineering Efficiency Department, which should be an additional common service department on the same footing as existing common service departments such as Design, Contracts or Finance, and which should stand in the same relations to the supply departments as these did. The Engineering Efficiency Department should be responsible for ensuring that contracts were " so placed and executed in the Works that by means of the machinery available and the smallest amount of skilled labour necessary the maximum output would be obtained." For this end the department would determine the allocation of machine tools, as well as the need for and nature of any new extensions to factories, and would give technical advice to contractors. To carry out these functions the department would be placed in charge of a Member of the Munitions Council specially responsible. The headquarters organisation would consist of a Controller to whose staff would be transferred some of the engineers employed in the supply departments, the Central Clearing House and the technical branch of the Labour Dilution Department. The outside organisation would consist of the field staff of the engineers at present reporting to the supply department and the Central Clearing House, under the control of a Chief Engineer who would be appointed to each of the different areas and who would work in close co-operation with the Labour Dilution Officer of the area.

(*c*) Effect of the Report on the Existing Organisation.

One of the strongest practical objections offered to the large scheme put forward by Sir Glynn West was that it would cut right across the existing organisation and necessitate a thorough re-arrangement of Ministry procedure at a time when all efforts should be directed towards obtaining the maximum output of munitions. In advising a modified scheme the committee aimed at reducing reorganisation to a minimum and hoped that the existing machinery of the supply departments would be very little disturbed. Each supply department was to retain all its existing responsibility for placing the contract, procuring drawings, providing raw materials, securing priority, arranging for labour and other requirements, and generally for the detailed supervision of the individual contract. The Engineering

Efficiency Department was simply to advise where the most suitable capacity was to be found, and during the course of the contract formulate from the returns obtained by the supply department statistics of efficiency as regards labour and machine capacity, by which means they would direct the efforts of their local engineers to the progressive improvement of productive methods and equipment. When extensions were necessary the Engineering Efficiency Department was to suggest which firm's plant was most suitable for extension and put forward a scheme, but the supply department would carry on the negotiations.

The problem of fitting in the local organisation of the new department to the existing Area Organisation was more difficult, but here again the principle was followed of making the least disturbance possible. The areas, area officers, and area secretary were to remain unchanged, and the local representatives of all departments other than supply departments would have their local headquarters as before in the Area Offices and be directed from headquarters at London. But all the local representatives of supply departments, together with the engineers of the Central Clearing House, were to be grouped together under a Chief Engineer in each area, who would be responsible to the Engineering Efficiency Department, but would be at the service of any supply department requiring local assistance which could correspond directly with the Chief Engineer if necessary.

This scheme was a compromise between the two divergent points of view. While leaving the supply departments their progress staff at headquarters, it removed from their control their local engineering staff; yet at the same time they were to continue to use those staffs for local purposes. Apparently therefore the local engineers were in the position of having to serve two masters. Moreover, it appeared to leave the contractor in the position of being open to visits from two sets of engineers, the Engineering Efficiency Department engineers for giving him advice for general efficiency, and the technical inspectors of the supply department, who might be sent down from headquarters to supervise an individual contract, if the department preferred this method to using the Engineering Efficiency Department's local staff. Locally, therefore, the scheme put forward in the report did but little to remove one of the gravest defects of the existing position. At headquarters also the report failed to carry out to any marked extent the views of those who advocated a strong executive control. The relative positions of the supply departments and the Engineering Efficiency Department under the new scheme reduced the latter to a purely advisory body with no authority to enforce its wishes as to the placing of contracts. The report of the committee necessitated the abandonment of the bolder and more progressive policy, and among other modifications which preceded the introduction of the scheme, the idea of making the Engineering Efficiency Department a common service department to the whole Ministry was abandoned for the time.

(*d*) Constitution and Functions of the Department.

It was thus under distinctly unfavourable circumstances that the Department of Engineering struggled into being. In March, 1918, the constitution of the department was announced. All the outside engineering staff of the departments within the Ordnance Group,[1] including the Outside Engineering Branch of the Trench Warfare Supply Department, were to form part of the staff, and the outside engineering staff in each area would constitute the Area Engineering Board, which would be responsible for the work hitherto carried out by the Area Clearing House Boards. The work of the Central Clearing House was also to be incorporated. The new organisation was to be the source of information within the Ministry on the technical aspects of ordnance production, and on the manufacturing programmes of the supply departments of the Ordnance Group. It was to prepare proposals for the interchange of machines and buildings in order to use capacity to the best advantage, and all the functions of the Central Clearing House with regard to the transference and release of machine tools were to come within its province. In addition it was to investigate cases of low efficiency, delays in delivery and other production problems at the request of the supply controllers, to advise how to improve production and to cut down supply where necessary with the least disturbance.

The limitation of the department to the Ordnance Group involved serious disadvantages, since it meant that all supply departments not within that group would continue to maintain their local staffs within the areas, independently of the organisation of the Department of Engineering. Thus the centralised local control which it was the object of the new arrangement to procure would largely disappear. This difficulty was particularly obvious in the case of the Machine Tool Department, whose organisation in the areas had overlapped considerably with the Clearing House system, and this had been a source of considerable friction in 1917. So long as the Machine Tool Department remained outside the Ordnance Group, there seemed little hope of minimising the friction. Accordingly it was decided in May, 1918, to bring the Machine Tool Department within the Ordnance Group. Automatically the Machine Tool Inspectors should then have been transferred to the staff of the Engineering Department. But it was not till July that the Machine Tool Department could be prevailed upon to waive its objections and accept the logical result of the step taken in May. Again the Ordnance Engineers, though within the Ordnance Group from the start, were not absorbed into the engineering staff till December, 1918, the objections of the Controller

[1] The Ordnance Group of departments within the Ministry comprised, in March, 1918, the Department of Gun Manufacture, the Gun Ammunition Manufacture Department, the Department of Gun Ammunition Filling, the Small Arms and Machine Guns Department, the Small Arms Ammunition Department, the Trench Warfare Supply Department, the Gauges Department, the Timber Supplies Department, the Central Clearing House, and the Department of Area Organisation.

of Gun Manufacture having taken ten months to overcome. In such circumstances it can be seen that the work of forming the Engineering Department was an uphill task. At its formation, in spite of the statement that it would include all the outside staff of the supply departments within the Ordnance Group, practically the only ones which it controlled were the Outside Engineers of the Trench Warfare Department, and the Area Clearing House Engineers. The drawing in of the Machine Tool Inspectors represented a step forward, and the inclusion of the Ordnance Engineers was a signal triumph for the perseverance of the Controller (Mr. E. V. Haigh).

Locally also, the re-organisation consequent upon the formation of the new department proved no easy task. Owing to the tardy co-operation of the supply controllers, any hard and fast organisation set up immediately upon the formation of the department ran the risk of having to be scrapped as soon as an advance was made: on the other hand, it was impossible to leave the reorganisation of the area staff until all arrangements had been made with all the supply controllers. Eventually an arrangement was evolved in August whereby the Superintending Engineer under the Area Organisation scheme was transferred to the Department of Engineering, and was to be the chief representative of the department in the area. The staff under his control was to be divided into sections, each section being detailed for the work of a particular supply department, and being in close touch with that department, though under the control of the Department of Engineering. Beneath these again were the assistant engineers who would be a free-lance staff, capable of being transferred from one section to another according to the pressure of work. This scheme was designed to obtain the central control of local production which experience had proved to be essential, while at the same time it would allow for expansion as the different supply departments were prevailed upon to allow their outside staffs to be incorporated. By simply adding new sections within the existing framework the organisation could be expanded till it fulfilled the original idea of its promoters, the inclusion of all outside staffs, not merely those of the Ordnance Group, under the control of the Area Engineer, who would be the local representative of the Department of Engineering and would work in co-operation with the local representatives of other common service departments like the Labour and the Munition Works Department at the common local head-quarters, the Area Office.

When the Armistice was signed the organisation of the new department, both centrally and locally was well advanced. Not only was it on its way to obtaining the position designed for it within the Ordnance Group, but it was also proving its value to other departments outside the group, and thus preparing the way for an extension of its functions to the logical end. Experience of the working of the department had shown that the fears expressed that the output of individual supplies would be jeopardised were not well grounded, and that departmental success could be attained as well by co-operation as by isolation.

The formation of the Department of Engineering, even though incomplete, illustrates the triumph of a principle, the principle of co-ordination and balanced effort between the parts of the organism to ensure the well-being of the whole. That principle had been clearly grasped by those who in 1915 had conceived the whole gigantic organisation, it had been lost sight of in the pressure of 1916 and 1917, when "getting the stuff out" was the primary object of all; it was returned to in 1918, because experience had proved that failure in principle involved failure in results. The period between the formation of the Department of Engineering and the termination of hostilities was not long enough for the scheme to reach its full development or prove its ultimate value, but there can be little doubt as to the soundness of the principles on which it was based.

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Note.—The present issue is subject to revision, and must be regarded as provisional.

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